Voluntary Environmental Programs as a Collusive Mechanism: Incentives, Design, and Welfare Effects

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Abstract

This paper considers the welfare effects of industry-wide voluntary pollution prevention initiatives in repeated oligopolies under the hypothesis that firms will join these programs and fulfill their objective if they are able to coordinate in the product market. Three initiative designs are considered to analyze the extent to which the benefits of such voluntary programs can outweigh their anti-competitive effects. The results show that when firms are able to coordinate on pollution prevention and emissions, prevention levels are voluntarily set above the status quo to deter deviations from the joint-profit maximizing output. However, government participation is necessary to approximate social optimality under a voluntary initiative.

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1 Introduction

In the last decade, environmental protection agencies have designed and implemented programs that encourage firms to abate and prevent emissions voluntarily above and beyond the levels mandated by law. Hundreds of firms have joined one or more of these initiatives.

The popularity of voluntary programs among policy makers is due to the constraints of conventional regulation and the belief that businesses may undertake pollution prevention efforts under voluntary programs than can not be imposed upon them solely through traditional instruments. Voluntary programs ease institutional demands (data gathering, monitoring and enforcement) and the requirements for regulated parties, and by including firms in policy decision making, reduce the potential opposition and disruption that firms can cause (European Environment Agency [1997], Nyborg [2000], Russell [2001]).

On the other hand, voluntary programs can restrict competition. The European Environmental Agency (EEA) declares that "[e]xperiences in Austria, e.g. in the waste sector, show that, where [voluntary programs] are agreed, a market economy can lead to distorted price structures, if competition is not promoted by government" (EEA, [1997]). Similar experiences include a program of the Dutch Association of Independent Tank Storage Companies to curb air pollution that resulted in price fixing and an agreement by the European Committee of Domestic Equipment Manufacturers (CECED) that limited output and increased price (Vedder, 2000).[1]

Why might businesses want to and how could they use voluntary programs as a mechanism to restrict competition? Firms would not invest in pollution prevention in order to reduce competition if collusion were costless. However, sustaining collusion requires that firms know when a defection occurs and who is responsible. In practice, such information is imperfect or

[1] Concerns about reduced competition are also raised by the fact that in some programs, partners represent a large percent of the industry. For example, the Voluntary Aluminum Industry Program Partners take over 94 percent of the U.S. primary aluminum production capacity, Natural Gas Star Program Partners represent over 65 percent of the transmission company pipeline miles and over 35 percent of U.S. natural gas production, and over 50 percent of the U.S. cement manufacturing capacity have joined the Climate Wise Program. Furthermore, voluntary programs are generally negotiated by and implemented through industry associations or industry leaders and there is statistical evidence that firms decide collectively whether to join or not a voluntary program (Khanna and Damon [1999], and Videras and Alberini [1999]).

unavailable. Hence, firms may be willing to trade off the cost of pollution prevention with the benefits of an institution that gathers information, coordinates and monitors actions, and provides data on which to base decisions. Voluntary environmental initiatives launched by environmental agencies in conjunction with industry and trade associations act as this institution. The members of the programs commit to submit progress and achievements reports making possible the monitoring of their emissions and, in some agreements, e.g. the CECED case, output. Voluntary programs also offer multiple occasions for contact and communication among the industry's members, and the standardization of technologies further facilitates coordination upon output.

This paper analyzes the design of voluntary programs whose benefits outweigh their anti-competitive effects under the presumption that firms would join a program and comply with its mandate if the initiative is a self-enforcing mechanism, that is, if firms participate following their own interest and have no incentives to defect.[2]

First, the paper studies general conditions under which the value of a voluntary program is larger than the cost to society of restricting competition. Next, three initiative designs are considered to analyze the extent to which industry's involvement in policy decision making can improve social welfare. In a Centralized Voluntary Initiative (CVI) the agency sets both pollution prevention and emissions that are socially optimal under a voluntary program and challenges businesses to join the initiative. A CVI is the benchmark that shows what the agency could ideally achieve given the nature of these initiatives. In the second design, a Partially Centralized Voluntary Initiative (PCVI), the agency concedes some power to the firms in the decision making process. The agency sets pollution prevention efforts, invites companies to adopt the new standard and reports actual prevention practices and emissions of member firms.[3] In a Decentralized Voluntary Initiative (DVI) the agency forgoes complete control over the initiative. The firms decide on both emissions and prevention practices and the agency reports emissions of

[2]In fact, the Commission of the European Communities approved the agreement of the CECED because its benefits outweighed the effects on competition and these were considered indispensable to fulfill the goal of the agreement.

[3]For example, under the Design for the Environment Program, the U.S.A. EPA and industry representatives evaluate different pollution prevention technologies and recommend alternatives according to their costs and human health and environmental risks without setting emissions reduction targets.

member firms.[4]

The paper does not intend to present a complete theory of voluntary programs. There is statistical and anecdotal evidence that public recognition and regulation preemption influence the firms' decision to join voluntary programs (Arora and Cason [1996], Khanna and Damon [1999], Maxwell *et al.*, [2000], and Videras and Alberini [2000]). However, in order to focus on concerns about competition, rather than assuming than reputation and regulation preemption are the driving factors in the formation of voluntary programs, in this model firms trade off the cost of pollution prevention with the benefits of collusion in the product market. Likewise, this paper does not compare voluntary initiatives to second-best regulatory instruments but focuses exclusively on the welfare implications of different types of voluntary agreements.[5]

The paper is organized as follows: Section 2 presents a two-stage model. In stage one (at time zero) the firms decide whether to join a voluntary program and adopt a certain level of pollution prevention. In the second stage (at time periods one and beyond), the firms compete in quantities taking pollution prevention as given. It is assumed that emissions are linked to production so that the monitoring of emissions by the agency offers a mechanism to detect departures from the agreed-upon level of output. Section 3 addresses the question of whether voluntary programs that restrict competition can improve welfare. Sections 4, 5, and 6 consider centralized, partially centralized, and decentralized initiatives, respectively. Section 7 concludes.

2 The model

Voluntary programs impose one-time administrative and set-up costs designated K. Participants undertake pollution prevention efforts that lead to emissions reductions. The level of prevention is denoted θ.[6] The increment

[4] The U.S.A. EPA programs Green Lights or Natural Gas STAR the U.S.A. EPA encourage businesses to reduce emissions without setting concrete prevention technologies and firm-specific goals.

[5] Nyborg (2000) compares voluntary agreements to second-best emissions taxes when a third party such as a court cannot verify emissions levels and concludes that the outcome of these agreements cannot be achieved through traditional regulation.

[6] For example, under the program 33/50 partners prevented emissions of chlorinated solvents through operational improvements of conventional processes, solvent substitution, recycling and recovering, and the adoption of alternative technologies.

in the marginal cost of production at θ is denoted $t(\theta)$. It is assumed that $t_\theta(\theta) \geq 0$. It is also assumed that $t_\theta(0) = 0$, reflecting the presumption that once fixed costs are paid, initial marginal reductions of emissions occur easily.[7] Pre-participation prevention efforts are normalized to zero.

The emissions function $e(q, \theta)$, where q denotes output, has the following properties:

$$e_q(\cdot) > 0, \quad e_\theta(\cdot) < 0, \quad \text{and} \quad e_\theta(q, 0) < 0.$$

Since $e_q > 0$, there exist an inverse function $q = e^{-1}(e; \theta)$, such that firms can infer output if, in addition to knowing θ, emissions are disclosed.[8]

Normalizing the monetary cost per unit of emissions to one, damage from total emissions is $D = \sum_{i=1}^{n} e(q_i, \theta_i)$ for $i = 1, ..., n$.[9]

The product market consists of n symmetric firms that engage in a two-stage game.[10] In stage one (at time zero), the firms decide whether or not to join a voluntary program, pay the one-time cost K, and adopt pollution prevention level θ. In the second stage (periods one and beyond) the firms compete in quantities taking θ as given. In the centralized and partially centralized initiatives the agency reports prevention levels and emissions. In a decentralized program the agency only discloses emissions.

The inverse market demand is given by $P : \mathcal{R}_+ \rightarrow \mathcal{R}_+$. Production cost is $C : \mathcal{R}_+ \rightarrow \mathcal{R}_+$, where $C(q)$ is assumed to be increasing. To guarantee the existence of an equilibrium in the second stage it is assumed that (i) marginal revenue is strictly decreasing: $P_q + qP_{qq} < 0$, and (ii) $C_{qq} - P_q > 0$.

In the absence of collusion in the product market, an equilibrium for the infinite-horizon market game consists of repeating the single-period Cournot

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[7] Pollution prevention can be accomplished by minor add-on improvements of conventional technologies, stewardship and training of workers. Therefore it is reasonable to presume that the first increment over the status quo in prevention efforts has a negligible impact on the firm's marginal cost once the fixed costs are paid. In the metal-finishing industry, for example, prevention efforts to reduce the use of chlorinated solvents in cleaning or degreasing can take the form of increasing the width of the tank opening where degreasing is completed.

[8] In the case of 33/50 this aspect was facilitated by the listing of targeted toxic substances in the Toxic Release Inventory (TRI). Although data in the TRI are believed to contain noise, the results of the model would remain unchanged so long as firms within an industry know or have a common prior probability over the distribution of noise.

[9] Although a convex damage function would be customary, I assume that damages are additive in per-firm emissions for tractability.

[10] It is assumed that there are substantial barriers to entry.

equilibrium in which each firm sets $\theta^{CN} = 0$, produces q^{CN} and earns single-period profits π^{CN}. In a collusive regime each firm produces q^* that maximizes the industry's joint-profits and solves

$$P(nq^*(\theta)) + q^*(\theta)P_q(nq^*(\theta)) - C_q(q^*(\theta)) - t(\theta) = 0, \qquad (1)$$

so that firms with a sufficiently high discount factor would participate in any initiative that allowed them to decide on emissions (or output) given θ.

3 Can Voluntary Initiatives Improve Welfare?

It is not obvious that a voluntary initiative that restricts competition will improve welfare. On the one hand, it results in less aggregate output and higher prices. On the other hand, the firms' profits increase and both improved pollution prevention efforts and the drop in output reduce emissions. The net impact on social welfare depends on the existing market conditions when the programs are implemented and the nature of the polluting activities covered.

Defining social welfare as the sum of consumer and producers surplus minus the dollar value of environmental damages:

$$W(nq, \theta) = \int_0^{nq} P(z)dz - nC(q) - nqt(\theta) - nK - ne(q, \theta),$$

a voluntary initiative would improve welfare if and only if at the status quo

$$\frac{dW(nq, \theta)}{d\theta} |_{\theta=0} = \frac{\partial W(nq, 0)}{\partial q}\frac{dq}{d\theta} + \frac{\partial W(nq, 0)}{\partial \theta} > 0.$$

Since under a voluntary initiative that restricts competition the firms compensate for their pollution prevention costs by reducing output it follows that $\frac{dq}{d\theta} < 0$. A minimal requirement to undertake pollution prevention is that at the status quo the benefit of mitigated environmental damages after a marginal increase in θ is known to be larger than the marginal cost of pollution prevention, that is, $\frac{\partial W(nq,0)}{\partial \theta} > 0$. Taking these facts into consideration, the next proposition provides sufficient and necessary conditions.

Proposition 1 *For a voluntary pollution prevention initiative to improve social welfare it is sufficient that at the initial equilibrium the marginal benefit* *of cutting back emissions through reduced economic activity is larger than or equal to the quantity distortion due to reduced competition. Otherwise, it is necessary that the marginal benefits of cutting back emissions through reduced economic activity* plus *the marginal benefit of pollution prevention are larger than the initial quantity distortion in the market.*

The first part of the proposition indicates that if it were socially desirable to abate emissions by reducing production, then an initiative that also brings in prevention efforts above the status quo would necessarily improve welfare.[11] The condition would be satisfied in a perfectly competitive market since welfare gains from reduced output levels, $\frac{\partial W(nq,0)}{\partial q}\frac{dq}{d\theta} = -ne_q(q,0)\frac{dq}{d\theta}$, are strictly positive. However, the larger the quantity distortion in the market the more environmentally damaging production activities and the more effective pollution prevention efforts must be for an initiative to increase welfare.

If the conditions of the proposition are fulfilled, the next question is to what extent a regulatory agency can rely on the firms' self-interest to improve welfare through a voluntary program. To address this issue, section 4 presents an initiative that results in the maximum level of welfare attainable under a voluntary program. This benchmark is compared in section 5 to a program in which the agency sets pollution prevention efforts and the firms agree upon emissions. Finally, section 6 considers a totally decentralized initiative in which the firms coordinate on both pollution prevention and emissions.

4 The Benchmark: A Centralized Voluntary Initiative

Consider a centralized initiative in which only participation is voluntary. The environmental agency establishes a specific prevention standard and emissions level or, equivalently, prevention standard and output. The agency's objective is to maximize social welfare subject to the incentive compatibility (IC) constraint that the present value of participation for each firm is greater than or equal to the present value of not accepting the agency's

[11] Indeed, the EPA acknowledges output reduction as a genuine way to prevent emissions. For example, the 33/50 program second report reveals that part of AT&T's reductions of its 33/50 chemicals were due to "decrease production levels at several of the company's plants" (USEPA [1992]).

scheme: $\pi(q,\theta) - (1-\delta)K \geq \pi^{CN}$. A slack IC constraint would imply that the firms are strictly better off participating in the initiative. Participation gains may result from increments in price whose effect on profits is not fully offset by the greater cost of pollution prevention.

The agency chooses q and θ that solve

$$\text{Max} \quad W(nq,\theta) = \int_0^{nq} P(z)dz - nC(q) - nqt(\theta) - nK - ne(q,\theta)$$
$$\text{subject to:} \quad \pi(q,\theta) - (1-\delta)K \geq \pi^{CN}.$$

The Lagrangian is:

$$L(nq,\theta) = \int_0^{nq} P(z)dz - nC(q) - nqt(\theta) - nK - ne(q,\theta) -$$
$$- \lambda[\pi(q,\theta) - (1-\delta)K - \pi^{CN}].$$

The first-order conditions of the problem are:

$$\frac{\partial L}{\partial q} \equiv n[P(nq) - C_q(q) - t(\theta) - e_q(q,\theta)] - \lambda[qP_q(nq) + P(nq) - C_q(q) - t(\theta)] = 0,$$
$$\frac{\partial L}{\partial \theta} \equiv -nqt_\theta(\theta) - ne_\theta(q,\theta) + \lambda qt_\theta(\theta) = 0,$$
$$\lambda \geq 0, \quad \pi(q,\theta) - (1-\delta)K \geq \pi^{CN}, \quad \lambda[\pi(q,\theta) - (1-\delta)K - \pi^{CN}] = 0.$$

Let θ^o and q^o be the socially optimal levels of pollution prevention and output that solve the conditions above.[12] Consider the solution corresponding to a nonbinding IC constraint ($\lambda = 0$). The optimal levels of output and prevention are given by

$$P(nq^o) - C_q(q^o) - t(\theta^o) - e_q(q^o,\theta^o) = 0, \tag{2}$$
$$-e_\theta(q^o,\theta^o) = q^o t_\theta(\theta^o). \tag{3}$$

Equation (2) indicates that at the socially efficient output and pollution prevention levels, the net market surplus that is lost as a result of a marginal reduction in q is equal to its marginal benefit on environmental quality. Equation (3) shows that the marginal benefit of increasing θ is equal to the marginal cost borne by the firms.

[12] Socially optimality refers here to the levels that can be attained in a voluntary initiative.

Suppose now that the firms' participation gains are entirely extracted ($\lambda > 0$). The optimal levels of output and prevention are given by

$$P(nq^o)q^o - C(q^o) - t(\theta^o)q^o = \pi^{CN} + (1-\delta)K, \tag{4}$$

$$-e_\theta(q^o, \theta^o) = q^o t_\theta(\theta^o) \frac{e_q(q^o, \theta^o) + q^o P_q(nq^o)}{P(nq^o) + q^o P_q(nq^o) - C_q(q^o) - t(\theta^o)}. \tag{5}$$

Equation (4) indicates that the IC constraint is binding. Equation (5) shows that the marginal benefit of increasing θ is equal to the marginal cost borne by the firms weighed by the relative impact of a larger θ on surplus, environmental quality and profits.

Information requirements would imperil the success of a Centralized Voluntary Initiative. Furthermore, businesses would oppose an initiative that may constrain profits to Cournot levels when joint-profit maximization could be achieved through a partially centralized or a decentralized program.

The next sections present two initiatives that reduce the demands for the regulatory agency and rely on the firms' self-interest to improve environmental quality and analyze their impact on welfare.

5 A Partially Centralized Voluntary Initiative

Consider an initiative in which the agency sets pollution prevention efforts and invites companies to join the initiative. Participants decide on that level of emissions that maximizes joint-profits taking θ as given. The agency observes prevention levels and emissions of member firms and chooses θ that solves

$$\text{Max} \quad W(nq^*(\theta), \theta) = \int_0^{nq^*(\theta)} P(z)dz - nC(q^*(\theta)) - nq^*(\theta)t(\theta) - nK - ne(q^*(\theta), \theta),$$

where $q^*(\theta)$ maximizes joint-profits given θ. The first-order condition

$$-e_\theta(q^*(\theta), \theta) - q^*(\theta)t_\theta(\theta) + \frac{dq^*(\theta)}{d\theta}[P(nq^*(\theta)) - C_q(q^*(\theta)) - t(\theta) - e_q(q^*(\theta), \theta)] = 0 \tag{6}$$

indicates that the marginal benefit of increasing θ is equal the marginal costs borne by the firms plus the net effect on social welfare weighed by the impact of θ on the industry's output.

Let $\hat{\theta}$ be the level of pollution prevention that solves (6). To facilitate the comparison with a centralized initiative, rearrange (6) as follows:

$$-e_\theta(q^*(\hat{\theta}),\hat{\theta}) = q^*(\hat{\theta})t_\theta(\hat{\theta}) + \frac{dq^*(\hat{\theta})}{d\theta}[q^*(\hat{\theta})P_q(nq^*(\hat{\theta})) + e_q(q^*(\hat{\theta}),\hat{\theta})], \qquad (6')$$

where I have used condition (1) to express the net effect on social welfare of reduced output as the sum of environmental benefits plus the firms' marginal profit due to reduced production.

5.1 Partially Centralized versus Centralized Initiative

Comparing conditions (1) and (6′) with (2)-(3) and (4)-(5), the following proposition follows:

Proposition 2 *A Partially Centralized Voluntary Initiative attains the social optimum if and only if the agency can set the level of pollution prevention efforts that equates marginal environmental benefits and the firms' marginal benefit due to reduced production.*

To illustrate the proposition suppose $P = 1 - bnq$, $t(\theta) = (1/2)\theta^2$, $C(q) = K = 0$, and $e(q,\theta) = Aq^2\theta^{-2}$. The agency achieves the social optimum under a voluntary program if it requires pollution prevention level $\hat{\theta} = \sqrt{\frac{2A}{nb}}$. In this event, marginal environmental benefits and marginal increase in profits are equal and conditions (2) and (1) are identical. Furthermore, $\hat{\theta}$ fulfils the optimality requirement that the marginal benefit of increasing θ is equal to the marginal cost borne by the firms. In that case, (3) = (6′), $\hat{\theta} = \theta^o$, and $q^o = q^*(\hat{\theta})$.

However, it is unlikely that the regulatory agency would be able to set the appropriate $\hat{\theta}$ and achieve the maximum level of welfare under a voluntary initiative. In order to do so, the agency ought to know the emissions function, market conditions, and what pollution prevention efforts and techniques are available and feasible, verify continuing compliance to prevention efforts, and disclose emissions.

6 A Decentralized Voluntary Initiative

Firms that join a decentralized program are able to coordinate their decisions on both pollution prevention and emissions (or, alternatively, output).

Regarding the choice of prevention efforts, the agency, firms and industry associations collaborate to gather information that provides a common benchmark that allows businesses to coordinate their choices. The disclosure by the agency of per-firm emissions allows firms to identify deviations from the agreement.

The next subsection uses the solution concept of subgame perfection to calculate the equilibria in the infinite-horizon quantity game.[13] Subsection 5.2 determines the Nash equilibrium in θ.

6.1 Equilibria in the repeated market game

Let $\pi^*(\theta)$ be single-period profits earned by each individual firm at q^* that solves equation (1); and $\pi^d(\theta)$ the single-period payoff for a firm that cheats optimally against the cartel.[14] Let $\overline{\theta}$ be the level of pollution prevention such that $\pi^*(\overline{\theta}) = \pi^{CN}$. That is, at $\overline{\theta}$ cartel profits would not be large enough to cover the fixed cost K so that firms would choose the business-as-usual equilibrium.

In case of defection participants of a VI resort to a "grim trigger" strategy.[15] Suppose $K \geq \pi^d(\theta) - \pi^{CN}$, for $\theta \in [0, \overline{\theta})$. Then, the discount factor at which profit-maximizing firms can support an agreement is $\delta(\theta) \geq 1 - \frac{\pi^*(\theta)-\pi^{CN}}{K}$. Suppose that $K < \pi^d(\theta) - \pi^{CN}$, for $\theta \in [0, \overline{\theta})$. Then, the discount factor that supports an agreement is $\delta(\theta) \geq \frac{\pi^d(\theta)-\pi^*(\theta)}{\pi^d(\theta)-\pi^{CN}}$.

In both cases $d\delta(\theta)/d\theta > 0$. The more intensive pollution prevention, the larger is the minimum discount factor at which collusion in the product market is feasible. Also, the larger the administrative and set-up costs of participation, the larger $\delta(\theta)$ is and the less likely is that firms will join a VI in order to coordinate in the product market. This result captures the observed fact that the funding of start-up costs by large firms and the agency is necessary for the success of the initiative and participation of small

[13]Subgame perfection guarantees that a collusive outcome is self-enforcing.

[14]Note that $d\pi^*(\theta)/d\theta \leq 0$. Using the Envelope Theorem, $\frac{d\pi^*(q^*(\theta),\theta)}{d\theta} = \frac{\partial\pi^*(q^*(\theta),\theta)}{\partial\theta} = -q^* t_\theta(\theta)$, that is less than or equal to zero. Also, $d\pi^d(\theta)/d\theta \geq 0$. Given the nature of the investment in pollution prevention, production processes are not affected irreversibly. In this case, a deviator sets $\theta = 0$. Since the partners' output decreases with θ, defection profits increase in the rivals' prevention costs.

[15]Appendix A presents the details of a "grim trigger" strategy and the derivation of the minimum discount factor that sustains collusion. Assuming a different strategy in case of defection will not alter the qualitative results of the model.

businesses (Reinhardt [2000]).

6.2 Equilibrium in the prevention level game

Since participation profits $\pi^*(\theta)$ are strictly decreasing in θ, the firms have the incentive to set prevention levels as close to zero as it is admissible. However, it could be possible for a firm to expand output and go unnoticed by increasing, covertly, pollution prevention so that emissions are kept at the agreed-upon level. Consequently, the firms would want to set the minimum level of prevention that deters deviation. In particular, the firms would choose θ^* such that the increase in output needed to emit $e^* = e(q^*, \theta^*)$ with more intense prevention efforts is insufficient to maintain profits at least at π^* after the increase in θ. Technically, the firms would agree upon the level of pollution prevention that equalizes the slopes of the isoemissions and isoprofits curves. The slope of the isoemissions curve is given by $\frac{dq}{d\theta} \mid_{e=e^*} = -\frac{e_\theta(q^*(\theta),\theta)}{e_q(q^*(\theta),\theta)}$. The increase in q that is needed to maintain profits at least at the joint-profit maximizing level after a marginal increase in θ, taking the other firms' output as given, is $\frac{dq}{d\theta} \mid_{\pi=\pi^*} = -\frac{\pi_\theta(q^*(\theta),\theta)}{\pi_q(q^*(\theta),\theta)}$. Hence, θ^* solves:

$$-\frac{e_\theta(q^*(\theta^*),\theta^*)}{e_q(q^*(\theta^*),\theta^*)} = \frac{q^*(\theta^*)t_\theta(\theta^*)}{P(nq^*(\theta^*)) + q^*(\theta^*)P_{q_i}(nq^*(\theta^*)) - C_q(q^*(\theta^*)) - t(\theta^*)}, \tag{7}$$

where $P_{q_i}(nq^*(\theta^*))$ indicates that the potential defector is taking the other firms' production as given.

Since $t_\theta(0) = 0$ and $-e_\theta(q, 0) > 0$, it follows that the equilibrium involves prevention efforts above the status quo, that is, $\theta^* > 0$. The intuition behind the result is that it is optimal to defect unless θ^* is set above the level at which inexpensive improvements are available.[16]

Hence, a decentralized voluntary program that functions effectively as a

[16] The existence of $\theta^* < \overline{\theta}$ cannot be guaranteed. Were $\theta^* \geq \overline{\theta}$ the cartel would not form unless the partners and agency decided to monitor prevention efforts as well as emissions. In practice, EPA's programs like 33/50 require the partners to submit annual progress reports that include pollution prevention practices. The agency, nonetheless, reports only "successful" efforts. Denote $\theta^s (< \overline{\theta})$ the minimum level of prevention that is considered "successful" by the agency. The disclosure of $\theta \geq \theta^s$ implies that a firm cannot undertake efforts equal to or larger than θ^s and maintain simultaneously emissions at e^* without being detected and punished. This imposes a kink on the isoprofits curve: it is not possible to increase θ beyond θ^s and maintain the cartel payoff. In consequence, firms adopt θ^* if $\theta^* < \overline{\theta}$; otherwise they undertake pollution prevention efforts θ^s.

collusive institution has two positive impacts on environmental quality. It improves pollution prevention efforts and firms reduce production and, hence, emissions.

The level of θ^* depends on the characteristics of the emissions function and market conditions. Suppose that $P = 1 - bnq$, $t(\theta) = (1/2)\theta^2$, $C(q) = K = 0$, and $e(q, \theta) = Aq^{\alpha}\theta^{-\beta}$. Then the firms voluntarily choose $\theta^* = \sqrt{\frac{2(n-1)\alpha\beta}{4n\alpha + (n-1)\beta}}$. The larger the emissions-output elasticity α the lower is θ^*. If α is relatively large, then the firms must invest more in pollution prevention efforts to keep emissions at the agreed-upon level after a increment of production and the less likely that defection is profitable. On the other hand, the larger the emissions-prevention elasticity β the larger is θ^*. The more environmentally effective θ is the easier and less costly is for a firm to deviate while maintaining emissions at e^* unless the industry agrees upon a sufficiently high level of pollution prevention. Finally, the more firms there are in the market the more difficult is to sustain collusion.

In sum, industries in which production activities are relatively clean (low α) and improvement in prevention efforts reduce substantially emissions (high β) will adopt the largest level of pollution prevention efforts voluntarily in order to deter deviations from the joint-profit maximizing output.

6.3 Decentralized Voluntary Initiative versus Centralized Initiative

In order to compare these initiatives it is helpful to write condition (7) as

$$-e_\theta(q^*, \theta^*) = q^* t_\theta(\theta^*) \frac{e_q(q^*, \theta^*)}{P(nq^*) + q^* P_{q_i}(nq^*) - C_q(q^*) - t(\theta^*)}. \qquad (7')$$

The next result follows.

Proposition 3 *A Decentralized Voluntary Initiative cannot attain the socially optimal levels of both emissions and θ.*

First, consider the case in which marginal benefits to the firms and marginal environmental benefits due to reduced production are equal at the optimum. The agency's and the firms' solution for $q(\theta)$ given θ coincide, (2) = (1). Social optimality requires the marginal benefit of higher prevention levels to be set equal to the marginal cost to the firms of adopting those levels.

In a DVI, however, the firms set θ^* such that the cost borne by the firms is less than the marginal environmental benefit of increasing θ. Therefore, (3) $\neq$ (7′). Compare now conditions (5) and (7′). The equations are identical except for the term $q^o P_q(nq^o)$ in (5). Were $\theta^o = \theta^*$ and $q^o = q^*$ then the left-hand side of (5) would be less than its right-hand side. Either the firms agree upon a level of θ that is lower than the level that equalizes marginal benefit and marginal costs of pollution prevention or the firms obtain an increment in benefit that exacerbates the market quantity distortion above what is socially optimal.

7 Summary

This paper considers the welfare effects of industry-wide voluntary pollution prevention initiatives in repeated oligopolies under the hypothesis that firms will join these programs if they are able to coordinate in the product market. Three initiative designs are considered to analyze the extent to which the benefits of such voluntary programs can outweigh their anti-competitive effects.

The results show that if the agency could gather accurate information about the emissions function, market conditions, and available pollution prevention techniques, and verify compliance with the standards, then a partially centralized program would be preferred over a totally decentralized program.

A decentralized initiative will not attain social optimality but it might still be preferred over the status quo if firms have hidden knowledge about the availability and effectiveness of prevention technologies. Two positive impacts on environmental quality take place when firms are able to coordinate on both pollution prevention and emissions. Firms reduce output and, therefore, emissions. This is the well-know result that a monopolist may have a favorable indirect effect on the quality of the environment because it tends to retard production (Hotelling [1931]). More importantly, a direct improvement of environmental quality is due to the fact that in order to deter deviations from the joint-profit maximizing output, oligopolists may voluntarily agree on a level of pollution prevention efforts that is significantly greater than the minimum level necessary for the voluntary agreement to be implemented. The largest improvements in environmental quality would take place in sectors where production activities are relatively clean and prevention efforts are more effective in reducing emissions.

If the goal of the government is to curb emissions in very polluting industries and approximate the maximum level of welfare then regulatory agencies must participate in the development of pollution prevention standards and be able and willing to carry the burden of increased information gathering and monitoring. Otherwise, a voluntary program that allows firms to agree upon the level of pollution prevention and emissions and enables them to coordinate in the product market will improve the quality of the environment particularly if production activities do not create large environmental damages and it is thought improvements in technologies are available and effective.

I assume identical firms. However, differences in production capacity and pollution prevention costs may play an important role in the use of VIs as a collusive mechanism. Firm heterogeneity would require computing a set of subgame perfect equilibria in the infinite-horizon game consisting of aggregate output and a market-sharing rule. Assuming symmetric firms also implies that firms decide unanimously whether or not to join a VI. Nonetheless, firm participation is rarely universal. An extension would be to explain how the equilibrium is reached in an industry in which participants do not want to drop the program and nonparticipants do not desire to join it.

8 Appendix A: Equilibria in the repeated quantity game

The following "grim trigger" strategy supports the collusive outcome q^* for every firm i:
$S_i^1 = q^*$,
$S_i^t = q^*$ if $q_j^\tau = q^*$, $\tau \in [1, ...t-1]$
$S_i^t = q^{CN}$ otherwise.

The necessary and sufficient conditions for this strategy to be a subgame perfect equilibrium are (1) the present value of single-period profits under the cartel must be larger than or equal to the present value of single-period profits under Cournot, and (2) the present value of the cooperative strategy is equal to or lager than the present value of defecting one period and reverting to the Cournot strategy in subsequent periods. Formally:

$$\frac{1}{1-\delta}\pi^*(\theta) - K \geq \frac{1}{1-\delta}\pi^{CN}$$

and,

$$\frac{1}{1-\delta}\pi^*(\theta) - K \geq \pi^d(\theta) + \frac{\delta}{1-\delta}\pi^{CN} - K,$$

where δ is the common discount factor.

The conditions above can be rewritten as:

$$\pi^*(\theta) - \pi^{CN} \geq (1-\delta)K$$

and,

$$\pi^*(\theta) - \pi^{CN} \geq (1-\delta)(\pi^d(\theta) - \pi^{CN}).$$

By inspection, one of these two conditions is redundant. Suppose $K \geq \pi^d(\theta) - \pi^{CN}$, for $\theta \in [0, \overline{\theta})$. Then

$$\delta(\theta) \geq 1 - \frac{\pi^*(\theta) - \pi^{CN}}{K}.$$

Suppose now that $K < \pi^d(\theta) - \pi^{CN}$, for $\theta \in [0, \overline{\theta})$. Then

$$\delta(\theta) \geq \frac{\pi^d(\theta) - \pi^*(\theta)}{\pi^d(\theta) - \pi^{CN}}.$$

9 Appendix C: Proofs

Proof of Proposition 1

Defining social welfare as the sum of consumer and producers surplus minus the dollar value of environmental damages:

$$W(nq, \theta) = \int_0^{nq} P(z)dz - nC(q) - nqt(\theta) - nK - ne(q, \theta),$$

taking the total derivative of this expression, and using the first order condition from the firms' problem, a VI could improve social welfare if at the initial equilibrium either

$$\text{(i)} \quad -q^{CN}P_q(nq^{CN}) \leq e_q(q^{CN}, 0), \quad \text{or}$$

$$\text{(ii)} \quad -e_\theta(q^{CN}, 0) - e_q(q^{CN}, 0)\frac{dq}{d\theta} > q^{CN}P_q(nq^{CN})\frac{dq}{d\theta}$$

Let $\tilde{q}$ be the level of output such that $-\tilde{q}P_q(n\tilde{q}) = e_q(\tilde{q}, 0)$. Then, if $q^{CN} < \tilde{q}$ condition (ii) must hold: the marginal benefit of cutting back emissions through prevention practices and reduced economic activity $(-e_\theta(q^{CN},0) - e_q(q^{CN},0)\frac{dq}{d\theta})$ must be larger than the marginal cost imposed on consumers $(q^{CN}P_q(nq^{CN})\frac{dq}{d\theta})$. At the initial equilibrium, a marginal increase in θ does not affect producers since it has been assumed that $t_\theta(0) = 0$. If $q^{CN} \geq \tilde{q}$, the planner can always improve welfare by reducing output and setting strictly positive prevention levels. ■

Proof of Proposition 2

Case (i): Consider the case in which $\lambda > 0$ in the CVI. Suppose that $q^*(\hat{\theta}) = q^o$ and $\hat{\theta} = \theta^o$. In that case, $P(nq^o) - C_q(q^o) - t(\theta^o) = -nq^oP_q(nq^o)$ and $-e_\theta(q^o,\theta^o) = \infty$ by (5), which is ruled out by the properties of the emissions function.

Case (ii): Consider the case in which $\lambda = 0$ in the CVI. Suppose that $q^*(\hat{\theta}) = q^o$ and $\hat{\theta} = \theta^o$. Then, conditions (1) and (2) are equal. Furthermore, $-nq^*(\hat{\theta})P(nq^*(\hat{\theta})) = e_q(q^*(\hat{\theta}),\hat{\theta})$ so that conditions (3) and (6′) coincide. ■

Proof of Proposition 3

Note that by Proposition 2 $q^*(\hat{\theta}) = q^o$ and $\hat{\theta} = \theta^o$ if and only if $-nq^*(\hat{\theta})P_q(nq^*(\hat{\theta})) = e_q(q^*(\hat{\theta}),\hat{\theta})$. By equation (6′) $-e_\theta(q^*(\hat{\theta}),\hat{\theta}) = q^*(\hat{\theta})t_\theta(\hat{\theta})$. However, by equation (7′) $-e_\theta(q^*(\theta^*),\theta^*) > q^*(\theta^*)t_\theta(\theta^*)$. Therefore, $\hat{\theta} \neq \theta^*$. ■

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