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ENVIRONMENTAL POLICY CHOICE: POLLUTION ABATEMENT SUBSIDIES

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CENTRE FOR INTERNATIONAL
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ABSTRACT

Environment Policy Choice: Pollution Abatement Subsidies

This paper first shows that subsidies to the input into pollution abatement are inefficient when a Pigouvian pollution tax is available. Using a model where the government receives political contributions from environmental and industry lobby groups, it then explains the use of pollution abatement subsidies in environmental policy as primarily being tools for redistribution. The pollution abatement subsidy and pollution tax are determined in political equilibrium. The equilibrium subsidy rate is shown to depend on the subsidy elasticities of pollution and abatement, and lobby group membership.

Key words: Instrument choice, pollution abatement subsidy, pollution tax, lobbying

JEL Codes: Q28, H11, H20

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NON-TECHNICAL SUMMARY

The purpose of this paper is twofold. First, we show that pollution abatement subsidies, defined as subsidies on the inputs to pollution abatement, are inefficient instruments for pollution control. Whereas these types of subsidies are used in practice, the existing literature analyses only subsidies to reductions in pollution from a base level. Second, we show how pollution abatement subsidies arise endogenously in a model with environmental and industry lobby groups, although an efficient pollution tax is feasible for the government. We predict the political equilibrium abatement subsidy and pollution tax levels, and argue that pollution abatement subsidies serve primarily as methods of redistribution.

The paper employs a menu auction model developed by Bernheim and Whinston (1986) and Grossman and Helpman (1994). Industry and environmental lobby groups offer the government prospective campaign contributions corresponding to different tax-subsidy policies in order to influence the policy outcome.

The intuition for how a positive equilibrium subsidy may arise despite being inefficient is the following. Imagine that we begin with the social optimum; a Pigouvian tax and a zero subsidy. If total pollution is decreasing in the subsidy rate, the subsidy benefits the environmentalists. The industrialists always gain from receiving the subsidy. The remaining groups in society pay a share of the subsidy, but derive no utility from it. Total welfare declines when we move away from the social optimum, but aggregate payoffs of the lobby groups and the government rise. Thus, the political equilibrium involves a positive subsidy. If, on the other hand, pollution is increasing in the subsidy the environmentalists are still better off if this is combined with a higher pollution tax, and cleaner production, than otherwise would emerge. However, the more distorting is the subsidy, the lower is the amount transferred in the political equilibrium.

1. INTRODUCTION

The purpose of this paper is twofold. First, we show that pollution abatement subsidies, defined as subsidies on the inputs to pollution abatement, are inefficient instruments for pollution control. Whereas these types of subsidies are used in practice, the existing literature analyses only subsidies to reductions in pollution from a base level [e.g., Mestelman, 1984,1989; Baumol and Oates, 1988; Kohn, 1992). Second, we show how pollution abatement subsidies arise endogenously in a model with environmental and industry lobby groups, although an efficient pollution tax is feasible for the government.[1] We predict the political equilibrium abatement subsidy and pollution tax levels, and argue that pollution abatement subsidies serve primarily as methods of redistribution. Hahn (1990) points out that "relatively little is known about the determination of subsidy levels", and that Becker's (1983) model "is not suited to answering questions about their observed levels".[2]

This paper employs a menu auction model developed by Bernheim and Whinston (1986) and Grossman and Helpman (1994). It is a complete information model where lobby groups offer the government menus of prospective campaign contribution levels corresponding to different tax-subsidy policies in order to influence the policy outcome.[3] The government maximizes the

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[1] Opschoor and Vos (1989) report 40 different subsidy systems in a sample of OECD countries. These subsidies take different forms: subsidy-charge systems, grants, soft loans, and tax allowances. These are given for abatement of waste, air, water, and noise pollution (Opschoor and Vos, 1989; Jenkins and Lamech, 1992).

[2] In this paper the government's policy choices are restricted to a pollution tax, pollution abatement subsidy scheme.

[3] According to Magelby and Nelson (1990), incumbents received over six times as much in PAC contributions as their challengers in the 1988 Congressional campaigns, open seats excluded. Furthermore, a major proportion of PAC funds were given early in the election cycle, or even to a winning candidate shortly after the election, although the opponent had been supported before the election. For an analysis of campaign contributions as investments, see

probability of being reelected in an implicit upcoming election. The electoral success depends on aggregate campaign contributions and aggregate social welfare.[4]

The intuition for how a positive equilibrium subsidy may arise despite being inefficient is the following. Imagine that we begin with the social optimum; a Pigouvian tax and a zero subsidy. If total pollution is decreasing in the subsidy rate, the subsidy benefits the environmentalists. The industrialists always gain from receiving the subsidy. The remaining groups in society pay a share of the subsidy, but derive no utility from it. Total welfare declines when we move away from the social optimum, but aggregate payoffs of the lobby groups and the government rise. Thus, the political equilibrium involves a positive subsidy. If, on the other hand, pollution is increasing in the subsidy the environmentalists are still better off if this is combined with a higher pollution tax, and cleaner production, than otherwise would emerge. However, the more distorting is the subsidy, the lower is the amount transferred in the political equilibrium.

Mestelman (1984, 1989) considers subsidies in environmental policy.[5] He uses a computerized general equilibrium model to investigate social choice of environmental policy instruments, but does not model lobby groups. Mestelman (1989) uses different endowment distributions and redistribution mechanisms to generate a case where majority rule voting provides

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Snyder (1990).

[4] A politician might also value contributions because these funds can be used to pay off campaign debts, deter challengers, show credibility as a candidate, or add to personal wealth. Hence, even if campaign spending has little effect on the election outcome, we can assume that the politician's welfare is increasing in campaign contributions.

[5] In a general analysis of the endogenous choice of regulatory instruments, Campos (1989) investigates the role of the legislature.

an inefficient resource allocation, e.g. standards and subsidies dominate taxes.[6] Fredriksson (1995) shows the effects on the pollution tax and pollution of an exogenous change in the pollution abatement subsidy rate.

The paper is organized as follows. Section 2 describes the model. Section 3 shows that pollution abatement subsidies are inefficient, characterizes the political equilibrium, and solves for the endogenous tax-subsidy pair. Finally, some comparative statics results are presented. Section 4 offers a summary.

2. THE MODEL

A small open competitive economy has two sectors producing a non-polluting numeraire good z and a polluting good x, respectively.[7] The economy is populated by individuals of three different types: workers, environmentalists, and industrialists, where the population is normalized to one. All types receive an exogenous labor income, but industrialists also obtain additional factor income from the production of good x. The environmentalists derive disutility from the pollution associated with the local production of good x. The three types of individuals have additively separable preferences.[8] Ignoring type-specific notation, the environmentalists' utility is given by

$$U^E = c_z + u(c_x) - \theta, \tag{1}$$

and the industrialists' and workers' utility is given by

[6] Mestelman (1984) shows that a pollution tax is consistently preferred to a subsidy by a majority of individuals.

[7] Many economies with implemented pollution taxes and abatement subsidies are small economies, e.g. the Netherlands and the Scandinavian countries.

[8] With quasi-linear preferences, corner solutions cannot be ruled out. We assume interior solutions.

$$U^I = U^W = c_z + u(c_x), \qquad (2)$$

where c_z is consumption of good z with world and domestic price equal to one, c_x is consumption of good x with world and domestic price equal to p^*, and $u(c_x)$ is a differentiable, strictly concave sub-utility function. An individual consumes $c_x = d(p^*)$ of good x, where the demand curve $d(p^*)$ is the inverse of $\partial u/\partial c_x$. The remaining spending equals c_z. Good x is manufactured by labor and a sector-specific input that is indivisible, non-tradeable and available in inelastic supply. The production technology is constant returns to scale. Production of good x results in a negative externality, given by the pollution function $\theta = \theta(X,A)$, where X is the quantity of good x supplied, and A is total pollution abatement costs. The pollution function θ is strictly convex in X, i.e. $\partial\theta/\partial X > 0$, and $\partial^2\theta/\partial X^2 > 0$. Abatement requires labor alone, and the technology exhibits diminishing returns to scale, i.e. $\partial\theta/\partial A < 0$, and $\partial^2\theta/\partial A^2 > 0$. Since pollution enters linearly in the environmentalists' utility function, the level of physical pollution translates directly into utility terms. The government has two instruments available: a per unit tax on pollution $t \in T$, $T \subset \mathbb{R}$, and a subsidy based on pollution abatement costs $s \in S$, $S \subset \mathbb{R}$. As will be shown below, the pollution abatement subsidy is an inefficient (transfer) instrument. We restrict ourselves to an inefficient transfer (subsidy) because with lump sum transfers the amount transferred may be infinite since these, with quasi-linear utility) are costless to the government. This implies that some individuals' consumption may be reduced below the subsistence level. Citizens behind a Rawlsian veil of ignorance, who can write the constitution ex ante, may therefore chose to commit to restrict the government's use of more efficient transfers in order to limit the amount transferred (see Brennan and Buchanan, 1977; Rodrik, 1986; Wilson, 1990). Grossman and Helpman (1994) argue that lobby groups may prefer inefficient transfers because such policies are associated with lower levels of campaign contributions. Fredriksson (1996) shows that in the case when a lump sum transfer is used, the Pigouvian tax is implemented.

Each individual has one unit of labor and total labor endowment equals l. Good z is produced with labor input only, a constant returns to scale technology, and an input-output coefficient equal to one. The supply of labor is assumed to be sufficiently large to secure a positive supply of z. In a competitive equilibrium the wage rate then equals one.

There are $n \geq 1$ identical firms producing good x. All firm specific notation is suppressed for simplicity. With p^* and the wage rate fixed, both the total supply of good x and total abatement are functions only of the tax and subsidy rates. Hence, given the government's policy choice (t,s), the solution to the firm's problem is given by the functions

$$[X(t,s), A(t,s)] = \underset{X,A}{argmax}\ \Pi, \tag{3}$$

where

$$\Pi = p^* X - C(X,A) - t\theta(X,A) + sA. \tag{4}$$

Total resource costs is represented by $C(X,A)=c_o X+A$, where $c_o>0$ is a parameter. Hence, $\partial C/\partial X>0$, $\partial C/\partial A>0$, $\partial^2 C/\partial X^2=0$, and $\partial^2 C/\partial A^2=0$. Furthermore, under plausible assumptions, $\partial X/\partial t<0$, $\partial X/\partial s>0$, $\partial A/\partial t>0$, and $\partial A/\partial s>0$.[9] With p^* and the wage rate fixed, the factor reward, owned jointly by the industrialists, can be written as $\Pi(t,s)$. The total net revenue equals

$$\tau(t,s) = t\theta(X(t,s), A(t,s)) - sA(t,s). \tag{5}$$

[9] See the appendix for these results.

The government is assumed to distribute (collect) $\tau(t,s)$ uniformly to (from) all individuals. All individuals with identical interests are assumed to organize into lobby groups, coordinating campaign contribution offers to the incumbent government. All environmentalists join the environmental lobby group, and all industrialists join the industry lobby group. Let i denote lobby group type, E (Environmental), I (Industry). Both the fraction of the population with membership and the total membership in lobby i is denoted by α^i. With fixed prices, the consumer surplus is constant. Ignoring constant terms, the utility of the environmental and industry lobby groups are, excluding campaign contributions, respectively

$$\Omega^E(t,s) \equiv \alpha^E\left[-\theta(X(t,s),A(t,s)) + l + \tau(t,s)\right], \tag{6}$$

$$\Omega^I(t,s) \equiv \Pi(t,s) + \alpha^I[l + \tau(t,s)], \tag{7}$$

where $-\alpha^E\theta(X(t,s),A(t,s))$ is the environmental lobby group's aggregated disutility from pollution and $\alpha^i[l+\tau(t,s)]$ is lobby group i's share of total labor income and net revenues. Each lobby group i makes campaign contributions $\Lambda^i(t,s)$ contingent on the policy pair (t,s). Only lobby group members make campaign contributions. Workers have an interest in large tax revenues and low subsidy expenditures. However, we assume that the workers are sufficiently numerous for collective action to be infeasible because of free-riding problems (see Olson, 1965). Moreover, their stake may be insufficient to have an incentive to organize. Disregarding direct organizing costs, let $\Omega^W(t^o,s^o)= \alpha^W[l+\tau(t^o,s^o)]$ be the equilibrium aggregate gross utility of the workers if organized into a lobby group, and $\Omega^W(t^{-W},s^{-W})=\alpha^W[l+\tau(t^{-W},s^{-W})]$ the gross utility of the workers if unorganized. Since labor income is exogenous, the difference in net revenues distributed (collected) is the only concern to workers. Assume that because of free-riding only a subset $\alpha^{Worg} < \alpha^{W}$ of the (otherwise homogeneous) workers are willing to join a worker lobby group. A sufficient condition for these workers to be unable to organize is that the implied campaign contribution per member exceeds the benefit obtained by each contributor. Formally, if $[\Omega^{W}(t^{o},s^{o})-\Omega^{W}(t^{-W},s^{-W})]/\alpha^{W} < \Lambda^{Wo}(t^{o},s^{o})/\alpha^{Worg}$, the benefit of joining the worker lobby group is insufficient for the workers to be able to form a lobby group (note that $\Lambda^{W}(t^{-W},s^{-W})=0$).[10] However, we assume that there is no free-riding within the organized lobby groups, and that $[\Omega^{i}(t^{o},s^{o})-\Omega^{i}(t^{-i},s^{-i})] > \Lambda^{io}(t^{o},s^{o})$, i=*E*,*I*. In addition, the lobby groups do not cooperate in their political action.

The incumbent government derives utility from campaign contributions and aggregate social welfare. Campaign contributions can be used for campaign spending, whereas a higher aggregate social welfare increases the probability of re-election, given that voters take their average welfare into consideration. The gross aggregate social welfare associated with the environmental policy pair (t,s) in the absence of contributions is given by

$$\Omega^{A}(t,s) \equiv -\alpha^{E}\theta(X(t,s),A(t,s)) + \Pi(t,s) + l + \tau(t,s). \tag{8}$$

Since only interest groups make campaign contributions, the government's utility function becomes

$$v^{G}(t,s) = \sum_{i\in E,I} \Lambda^{i}(t,s) + a\Omega^{A}(t,s), \tag{9}$$

where $a \geq 0$ is the government's weight on aggregate social welfare relative to campaign contributions.

3. THE POLITICAL EQUILIBRIUM

The model defines a two stage game between the incumbent government and the lobby

[10] Note that if $[\Omega^{W}(t^{o},s^{o})-\Omega^{W}(t^{-W},s^{-W})] > \Lambda^{Wo}(t^{o},s^{o})$, the workers would benefit from political organization.

groups. In the first stage, each lobby group i simultaneously offers the government a campaign contribution schedule $\Lambda^i(t,s)$, taking as given the other lobby group's schedule. A lobby group's strategy consists of a function $\Lambda^i: T \times S \to \mathbb{R}_+$, i.e. $\Lambda^i(t,s)$ maps every feasible environmental policy pair (t,s) into a campaign contribution level. In the second stage, the government selects a policy pair (t,s) from its two dimensional choice set (T,S), and receives the associated campaign contributions. The government's strategy is a policy vector that maximizes its total utility, given the lobby groups' strategies. The lobby groups are assumed to keep their promises in the second stage. Contributions are non-negative but an unfavorable policy, however, may induce a zero contribution. Lobby i receives gross monetary payoffs described by the continuous function $\Omega^i: T \times S \to \mathbb{R}_+$.

A set of schedules $\{\Lambda^{io}\}_{i \in E,I}$, and a policy pair (t^o,s^o) is a *Subgame Perfect Nash Equilibrium* if each schedule Λ^{io} is feasible for lobby i, i.e. non-negative and equal or less than the members' aggregate income; the policy pair (t^o,s^o) maximizes the government's welfare taking the offered schedules as given; and given lobby j's schedule, $\{\Lambda^{jo}\}_{j \neq i}$, and the government's anticipated decision rule, no lobby i has a feasible strategy that dominates the equilibrium strategy.

Proposition 1 in Grossman and Helpman (1994) implies that we can characterize the equilibrium with two necessary conditions:[11,12]

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[11] The governments's continuous choice set (T,S) is assumed to be bounded so that each environmental policy pair (t,s) lies in the interior of T and S, respectively. The tax or subsidy might reach the boundary of (T,S) if either lobby group's total income is insufficient to compete with the other lobby group. The aggregate income might be lower than the required contributions. Alternatively, the subsidy might become so large that total income is insufficient to finance it.

[12] Condition (C1) stipulates that the government determines the tax-subsidy policy pair to maximize its own welfare, given the offered contribution schedules. Condition (C2) states that the equilibrium tax-subsidy pair selected

$$(t^\circ, s^\circ) = \underset{t,s}{argmax} \sum_{i \in E,I} \Lambda^{i^\circ}(t,s) + a\Omega^A(t,s) \quad \text{on } (T,S); \tag{C1}$$

$$(t^\circ, s^\circ) = \underset{t,s}{argmax} \; \Omega^j(t,s) - \Lambda^{j^\circ}(t,s) + \sum_{i \in E,I} \Lambda^{i^\circ}(t,s) + a\Omega^A(t,s) \quad \text{on } (T,S) \; \forall j. \tag{C2}$$

Assume that the contribution schedules are differentiable around the equilibrium point (t^o, s^o). Conditions C1 and C2 imply that the following condition holds at the equilibrium policy pair (t^o, s^o):

$$\nabla\Omega^i(t^\circ, s^\circ) = \nabla\Lambda^{i^\circ}(t^\circ, s^\circ), \qquad \forall \; i. \tag{10}$$

Equation (10) implies *locally truthful* contribution schedules around the equilibrium point. The marginal change in the contribution for a small change in policy equals the effect of that policy change on the lobby group's gross welfare. Substituting (10) into the FOC of C1, we obtain

$$\sum_{i \in E,I} \nabla\Omega^i(t^\circ, s^\circ) + a\nabla\Omega^A(t^\circ, s^\circ) = 0. \tag{11}$$

Equation (11) is the equilibrium characterization of the tax-subsidy pair that is supported by differentiable contribution functions. As showed in Grossman and Helpman (1994), this implies that the government puts a weight of $(1+a)$ on the lobby group members' utility and a weight of a on the remaining population's utility.

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maximizes the joint welfare of each lobby j and the government, given the other lobby's equilibrium schedule. This has to be true since lobby j could otherwise change its schedule to induce the government to select the jointly optimal tax-subsidy pair, and capture most of the surplus from the policy change. Since the government would select the new policy, and lobby j would benefit from the change, the original tax-subsidy policy could not have been an equilibrium. For a complete set of necessary and sufficient conditions, see Bernheim and Whinston (1986).

Proposition 1: *In the absence of any lobby groups, the government selects a pollution tax, pollution abatement subsidy pair* (t°,s°) *equal to* (α^E,0).

Proof. First, to calculate the partial derivative of (7), the first-order conditions of (4) are needed:

$$\frac{\partial \Pi}{\partial X} = p^* - \frac{\partial C}{\partial X} - \frac{\partial \theta}{\partial X} t = 0, \tag{12a}$$

$$\frac{\partial \Pi}{\partial A} = -\frac{\partial C}{\partial A} - \frac{\partial \theta}{\partial A} t + s = 0. \tag{12b}$$

Without lobby groups, the partial derivatives of (8) become the government's first order conditions. Using (12a) and (12b) yields:

$$\frac{\partial \Omega^A(t,s)}{\partial t} = (t-\alpha^E)\left(\frac{\partial \theta}{\partial X}\frac{\partial X}{\partial t} + \frac{\partial \theta}{\partial A}\frac{\partial A}{\partial t}\right) - s\frac{\partial A}{\partial t}, \tag{13a}$$

$$\frac{\partial \Omega^A(t,s)}{\partial s} = (t-\alpha^E)\left(\frac{\partial \theta}{\partial X}\frac{\partial X}{\partial s} + \frac{\partial \theta}{\partial A}\frac{\partial A}{\partial s}\right) - s\frac{\partial A}{\partial s}. \tag{13b}$$

Setting (13a) and (13b) equal to zero, and solving for t and s yields

$$t^\circ = \frac{s^\circ \dfrac{\partial A}{\partial t}}{\dfrac{\partial \theta}{\partial X}\dfrac{\partial X}{\partial t} + \dfrac{\partial \theta}{\partial A}\dfrac{\partial A}{\partial t}} + \alpha^E, \tag{14a}$$

$$s^\circ = \frac{(t^\circ - \alpha^E)}{\dfrac{\partial A}{\partial s}}\left(\frac{\partial \theta}{\partial X}\frac{\partial X}{\partial s} + \frac{\partial \theta}{\partial A}\frac{\partial A}{\partial s}\right). \tag{14b}$$

Substituting (14a) into (14b) yields

$$s^{\circ}\left[\frac{\partial A}{\partial s}\left(\frac{\partial\theta}{\partial X}\frac{\partial X}{\partial t}\right)-\frac{\partial A}{\partial t}\left(\frac{\partial\theta}{\partial X}\frac{\partial X}{\partial s}\right)\right]=0. \tag{15}$$

The parenthesis in (15) is negative, and consequently $s^{\circ}=0$ => equation (14a) => $t^{\circ}=\alpha^{E}$. □

The welfare maximizing government sets a zero subsidy and the tax rate equals the number of environmentalists, i.e. the marginal disutility to society. This result serves as a benchmark for further discussion of the lobby group model.[13]

We now examine the subsidy and tax rates rate that arise when the lobby groups participate in the political process. Define $\xi^{\circ}=(\partial\theta/\partial X)(\partial X/\partial t)t/\theta<0$ as the tax elasticity of supply induced pollution, $\lambda^{\circ}=(\partial\theta/\partial X)(\partial X/\partial s)(s/\theta)>0$ as the subsidy elasticity of supply induced pollution, $\mu^{\circ}=(\partial\theta/\partial A)(\partial A/\partial s)(s/\theta)<0$ as the subsidy elasticity of abatement controlled pollution, $\epsilon^{\circ}=(\partial\theta/\partial A)(\partial A/\partial t)(t/\theta)<0$ as the tax elasticity of abatement controlled pollution, $\eta^{\circ}=(\partial A/\partial s)(s/A)>0$ as the subsidy elasticity of abatement, and $\beta^{\circ}=(\partial A/\partial t)(t/A)>0$ as the tax elasticity of abatement. In order to keep expressions (16) and (18) relatively simple, we have chosen to let t and s appear in both equilibrium equations.[14] In order to illuminate the lobby group pressures, let I^{i}, $i\in E,I$, be an indicator variable that equals one.

[13] Note that Proposition 1 relates to the Diamond and Mirrlees (1971) result that shows the suboptimality of subsidies and taxes on intermediate goods. The efficient combination of abatement and output requires the Pigouvian tax alone. The pollution abatement subsidy distorts the price of the input used for reducing pollution, and thus efficiency is not achieved.

[14] The completely solved expressions for s° and t° are available from the author on request.

Proposition 2: *In the presence of lobby groups, the government selects an equilibrium pollution abatement subsidy rate that satisfies*

$$s^{\circ}=\frac{[-\alpha^{E}(I^{E}+a)+t(\alpha^{E}+\alpha^{I}+a)](\lambda^{\circ}+\mu^{\circ})\theta^{\circ}}{[(\alpha^{E}+\alpha^{I}+a)(1+\eta^{\circ})-(I^{I}+a)]A^{\circ}}, \tag{16}$$

given the pollution tax.

Proof. Using (7), (12a), and (12b) we obtain

$$\frac{\partial\Omega^{E}(t,s)}{\partial s}=\alpha^{E}\left[(t-I^{E})\left(\frac{\partial\theta}{\partial X}\frac{\partial X}{\partial s}+\frac{\partial\theta}{\partial A}\frac{\partial A}{\partial s}\right)-A-s\frac{\partial A}{\partial s}\right], \tag{17a}$$

$$\frac{\partial\Omega^{I}(t,s)}{\partial s}=AI^{I}+\alpha^{I}\left[\left(\frac{\partial\theta}{\partial X}\frac{\partial X}{\partial s}+\frac{\partial\theta}{\partial A}\frac{\partial A}{\partial s}\right)t-A-s\frac{\partial A}{\partial s}\right]. \tag{17b}$$

Substitute (13b), (17a) and (17b) into (11), rearrange, and solve for s°. □

Assume that the denominator of (16) is positive. The environmental lobby group bids for a lower (higher) subsidy rate in equilibrium if total pollution is increasing (decreasing) in the subsidy rate [i.e. if $(\lambda^{\circ}+\mu^{\circ})>(<)0$]. The industry lobby group bids for a higher subsidy rate since the second term $(I^{I}+a)A^{\circ}$ reduces the denominator. These are the expected directions of the pressures from the two lobby groups. The intuition for how a positive equilibrium subsidy may arise is the following. Imagine that we begin with the social optimum as stated in Proposition 1. If total pollution is decreasing in the subsidy rate, the subsidy benefits the environmentalists. The industrialists also are better off from receiving the subsidy. Total welfare declines, but aggregate payoffs of the lobby groups and the government rise. Thus, the political equilibrium involves a positive subsidy. If, however, pollution is increasing in the subsidy, the environmentalists may still be better off if this is associated with a lower pollution due to a higher pollution tax than otherwise would have emerged. If the denominator of (16) is negative, the political pressures are reversed in equilibrium. This is the case for a sufficiently small subsidy elasticity of abatement, η°.

Proposition 3: *In the presence of lobby groups, the government selects an equilibrium pollution tax that satisfies*

$$t^{\circ} = -\frac{\alpha^{E}(I^{E}+a)(\xi^{\circ}+\epsilon^{\circ})\theta^{\circ}+(\alpha^{E}+\alpha^{I}+a)s\beta^{\circ}A^{\circ}}{[(I^{I}+a)-(\alpha^{E}+\alpha^{I}+a)(\xi^{\circ}+\epsilon^{\circ}+1)]\theta^{\circ}}, \tag{18}$$

given the pollution abatement subsidy rate.

Proof. Using (12a) and (12b), taking the partial derivatives of (6) and (7) yield

$$\frac{\partial\Omega^{I}(t,s)}{\partial t} = -\theta I^{I}+\alpha^{I}\left[\left(\frac{\partial\theta}{\partial X}\frac{\partial X}{\partial t}+\frac{\partial\theta}{\partial A}\frac{\partial A}{\partial t}\right)t+\theta-s\frac{\partial A}{\partial t}\right], \tag{19a}$$

$$\frac{\partial\Omega^{E}(t,s)}{\partial t} = \alpha^{E}\left[(t-I^{E})\left(\frac{\partial\theta}{\partial X}\frac{\partial X}{\partial t}+\frac{\partial\theta}{\partial A}\frac{\partial A}{\partial t}\right)+\theta-s\frac{\partial A}{\partial t}\right], \tag{19b}$$

Substitute (13a), (19a), and (19b) into (11), rearrange, and solve for t°. □

Substituting (16) into (18) implies $\alpha^E+\alpha^I=1 \Rightarrow t^\circ=\alpha^E \Rightarrow s^\circ=0$. When all individuals are lobby group members, the maximization of the lobby groups utility equals the maximization of aggregate welfare, and the efficient tax and subsidy rates are selected (see Proposition 1). Second, as the government's weight on social welfare, a, increases, the tax and subsidy approach α^E and zero, respectively. In all other cases, the lobby groups influence the subsidy and tax such that they deviate from the efficient levels, except by chance. Comparative statics yield further insights into the determination of the equilibrium pollution abatement subsidy.

Proposition 4: *In equilibrium, s° is increasing (decreasing) in λ° if, on the margin, tax revenues are more (less) important to the government than disutility from pollution, given the tax.*

Proof. Total differentiation of (16) yields

$$\frac{ds^\circ}{d\lambda^\circ}\Big|_t = \frac{[\alpha^E(I^E+a)-t^\circ(\alpha^E+\alpha^I+a)]\theta^\circ}{(-\alpha^E(I^E+a)+(\alpha^E+\alpha^I+a)t^\circ)(\lambda^\circ+\mu^\circ)\mu^\circ\theta^\circ/s^\circ+A^\circ(1+\eta^\circ)[I^I+a-(\alpha^E+\alpha^I+a)(1+\eta^\circ)]},$$

where $|_t$ means that we hold t° constant. The denominator is assumed negative because it is the second-order condition of (11), which characterizes a maximum. Hence, $ds^\circ/d\lambda^\circ|_t>(<)0$ if $t^\circ(\alpha^E+\alpha^I+a)>(<)\alpha^E(I^E+a)$, i.e. if the political pressure for tax revenues is larger (smaller) than the political pressure for lower pollution. □

Proposition 5: *In equilibrium, s° is increasing (decreasing) in μ° if, on the margin, tax revenue is more (less) important to the government than disutility from pollution, given the tax.*

Proof. Total differentiation of (16) yields

$$\frac{ds^{\circ}}{d\mu^{\circ}}\Big|_t = \frac{[\alpha^E(I^E+a)-t^{\circ}(\alpha^E+\alpha^I+a)]\theta^{\circ}}{(-\alpha^E(I^E+a)+(\alpha^E+\alpha^I+a)t^{\circ})(\lambda^{\circ}+\mu^{\circ})\mu^{\circ}\theta^{\circ}/s^{\circ}+A^{\circ}(1+\eta^{\circ})[I^I+a-(\alpha^E+\alpha^I+a)(1+\eta^{\circ})]},$$

where $|_t$ means that we hold t° constant. The denominator is assumed negative because it is the second-order condition of (11), which characterizes a maximum. Hence, $ds^{\circ}/d\mu^{\circ}|_t$ >(<)0 if $t^{\circ}(\alpha^E+\alpha^I+a)$>(<)$\alpha^E(I^E+a)$, i.e. if the political pressure for tax revenues is larger (smaller) than the political pressure for lower pollution. □

Proposition 6: *In equilibrium, s° is increasing (decreasing) in η° if, on the margin, net revenues are more (less) important to the government than disutility from pollution, given the tax.*

Proof. Note that $\eta^{\circ}(\partial\theta/\partial A)=\mu^{\circ}$. After the appropriate substitutions in (16), total differentiation yields

$$\frac{ds^{\circ}}{d\eta^{\circ}}\Big|_t = \frac{[\alpha^E(I^E+a)-t^{\circ}(\alpha^E+\alpha^I+a)](\partial\theta/\partial A)\theta^{\circ}+(\alpha^E+\alpha^I+a)A^{\circ}s^{\circ}}{\begin{array}{c}[(-\alpha^E(I^E+a)+(\alpha^E+\alpha^I+a)t^{\circ})(\lambda^{\circ}+\mu^{\circ})\mu^{\circ}\theta^{\circ}/s^{\circ}+A^{\circ}(1+\eta^{\circ})[I^I+a-(\alpha^E+\alpha^I+a)(1+\eta^{\circ})]\\ +[(\alpha^E+\alpha^I+a)t^{\circ}-\alpha^E(I^E+a)](\partial^2\theta/\partial A\partial A)(\partial A/\partial s)\eta^{\circ}]\end{array}}$$

where $|_t$ means that we hold t° constant. The denominator is assumed negative because it is the second order condition of (11). The negative change in the pressure for net tax revenue is represented by $(\alpha^E+\alpha^I+a)(A^{\circ}s^{\circ}-t^{\circ}(\partial\theta/\partial A)\theta)$, and $\alpha^E(I^E+a)(\partial\theta/\partial A)\theta$ is the positive effect of environmental lobby group pressure. □

The main point is that the subsidy policy is used to reduce the industry's costs associated with the tax policy (higher abatement and lower output) at the expense of the remaining groups. The subsidy enables the government to reduce the loss of political support associated with using the tax policy, without losing fully the support of the environmental lobby group. However, a pollution abatement subsidy which is more costly in terms of welfare is associated with a lower equilibrium subsidy rate. Hence, the income transfer (the compensation) falls endogenously with the inefficiency of the type of subsidy used.

4. SUMMARY

The environmental policy literature lacks a theory that explains the use of pollution abatement subsidies and predicts their levels. This paper aimed to fill this gap. We employed a model where environmental and industry lobby groups influence government environmental policy with campaign contributions. First, we analyzed a policy scheme restricted to a pollution tax and a pollution abatement subsidy and showed that a welfare maximizing government sets the Pigouvian tax rate and a zero subsidy. Thus, pollution abatement subsidies are inefficient instruments for pollution control. Second, we found the equilibrium pollution abatement subsidy and pollution tax levels in the political equilibrium. The intuition is the following. In order to obtain the political support from the environmentalists, the government implements a pollution tax. The pollution tax, however, reduces profits and thus the political support from the industry lobby group. In order to reduce the fall in industry political support the government uses a compensating transfer in the form of a pollution abatement subsidy. The equilibrium level of the subsidy depends on the size of the associated distortions created, i.e., a more distorting subsidy implies a smaller amount transferred.

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APPENDIX

Consider the following expressions derived from the second-order conditions for profit maximization:

$$\frac{\partial X}{\partial t} = t\left(-\frac{\partial\theta}{\partial X}\frac{\partial^2\theta}{\partial A^2} + \frac{\partial\theta}{\partial A}\frac{\partial^2\theta}{\partial X\partial A} \right) / |D|, \tag{A1}$$

$$\frac{\partial A}{\partial t} = t\left(-\frac{\partial\theta}{\partial A}\frac{\partial^2\theta}{\partial X^2} + \frac{\partial\theta}{\partial X}\frac{\partial^2\theta}{\partial A\partial X} \right) / |D|, \tag{A2}$$

$$\frac{\partial X}{\partial s} = -t\left(\frac{\partial^2\theta}{\partial X\partial A} \right) / |D|, \tag{A3}$$

$$\frac{\partial A}{\partial s} = t\left(\frac{\partial^2\theta}{\partial X^2} \right) / |D|, \tag{A4}$$

where D is the matrix of partial derivatives formed from second-order conditions for profit maximization. Satisfying second-order conditions requires $|D|>0$. We have assumed $\partial\theta/\partial X>0$, $\partial\theta/\partial A<0$, $\partial^2\theta/\partial X^2>0$, and $\partial^2\theta/\partial A^2>0$ and hence (A4) is unambiguously positive. However, we have no prior information of the signs of the cross-partials, although they are likely to be non-positive. Assuming $\partial^2\theta/\partial A\partial X$ and $\partial^2\theta/\partial X\partial A$ are negative and small in absolute value relative to the other terms, our assumptions hold for (A1), (A2) and (A3). However, if they are negative and large in absolute value, it is possible that $\partial X/\partial t>0$, $\partial A/\partial t<0$, and $\partial X/\partial s<0$, although the chance seems remote.

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