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Why the Weak Win:
The Strategic Role of Investment in Lobbying

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ABSTRACT

Old and environmentally damaging industries often lobby effectively for less stringent regulations and are slow to adopt new and cleaner technologies. This paper explains the lobbying success of these industries in terms of the strategic role of investment as a credible commitment device. It is demonstrated that if governments are predisposed to special interest groups, underinvestment in new technology enables firms to lobby more effectively. Such industries are shown to be better placed to extract policy concessions, despite contributing less to the government in political donations. The analysis therefore suggests that political considerations may provide a significant incentive for firms to reject environmentally beneficial investments, even when these lower production costs.

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1. INTRODUCTION

A growing body of empirical literature suggests that older industries often form highly effective lobby groups, which resist reforms such as the introduction of environmental regulations, or the elimination of trade barriers.[i] Moreover, while successful in lobbying, such industries have often been slow to adopt cleaner and more efficient technologies. This observation has lead some commentators to argue that investment in environmental damage control can be profitable, in the sense that a firm can more than offset the initial investment through cost savings. For instance, Porter and Linde [27] provocatively assert that:

> "*Actual experience with environmental investments illustrates that in the real world, $10 bills are waiting to be picked up*."[ii]

This paper seeks to explore the reasons why environmentally damaging industries appear to be more successful at securing policy concessions and are often slow to embrace new technologies. We propose a novel explanation, which focuses upon the role of investment in technology as a credible commitment device. It is shown that the lobbying success of an industry depends critically upon its prior investment strategy. Firms that underinvest in "clean" technologies, can lobby more successfully for policy concessions. This occurs because underinvestment in new technology acts as a credible commitment device, which makes environmental reform difficult for the government and thus renders lobbying more effective. In what follows, we demonstrate that there exist circumstances in which firms may reject cost saving investments in order to elicit a favourable response from the government.

The analysis is based on a simple framework, which deals with the problem of pollution control. We consider a firm which emits pollution that adversely effects a subset of individuals in the economy.[iii] In order to control the level of pollution the government levies an emissions tax on the firm. The resulting emission levels depend upon the degree of environmental regulation (i.e. the tax rate) and the level of investment in pollution abatement equipment.

Lobbying is introduced into this framework by drawing on the model of political competition developed by Grossman and Helpman [18], and extended by Fredriksson [15]. Accordingly, it is assumed that a self-interested government cares not only about aggregate welfare, but also political contributions received from lobby groups. Political donations influence the government's decisions because of their many uses, including funding election campaigns, retiring debt from previous elections and deterring rivals. It is assumed that the firm seeks to minimize its tax burden by offering political contributions to the government, which are contingent on the emission tax policy implemented. The government in turn, selects the policy that maximizes its own welfare. Since the analysis focuses upon the effects of lobbying by polluters, the role of an opposing environmental lobby group is suppressed. This may be justified by assuming that pollution damage is so widely dispersed that it does not induce the affected individuals to form a lobby group. In the parlance of Baron [5] this represents a *particularist* policy, where the benefits of a tax concession are concentrated, but the environmental costs are so thinly spread that they do not provide sufficient incentive for individuals to organize a lobby group, or make political donations.

As noted by Grossman and Helpman [18] this approach to modelling political lobbying is well suited to analyse the precise details of policies which are likely to be adopted by a government. The longer-term impact of policies on the election outcome is ignored, on the assumption that the incumbent government has some measure of flexibility in making policy choices. The analysis may therefore be viewed as focusing upon the short-term determinants of policies, within a given political and economic structure.

We assume the following sequence of events. In the first stage, the firm chooses a pollution abatement technology. The second stage determines the political equilibrium, in which the firm selects a contribution schedule and the government sets the emission tax rate. In the final stage the firm sets output and abatement levels. [iv]

This paper extends the existing literature by exploring the impact of firm investment on environmental policy outcomes. We consider a situation in which firms can choose between a continuum of pollution abatement technologies, which differ in their associated abatement costs. Not unrealistically, it is assumed that technologies which are more efficient, in the sense that they abate a given amount of pollution at lower cost, necessitate higher levels of investment.[v] The technologies can therefore be ranked, since the pollution abatement costs for one technology are lower (higher) than they are for another. It is demonstrated that if the government values political donations, underinvestment in pollution abatement technology enables firms to lobby more effectively for a lower pollution tax. Intuitively, this reflects the fact that in a political equilibrium, the tax rate which is set by the government depends on the level of political contributions, and the welfare costs of the chosen policy. By adopting a less efficient abatement technology, the firm raises the cost of reducing pollution and thus renders a pollution tax less effective.[vi] Pollution control is made more difficult for the government to achieve and the firm therefore needs to spend less on lobbying.

In deciding on whether to invest in more efficient pollution abatement equipment, the firm will trade off the benefits which accrue in the form of lower production costs, against the need to spend more on lobbying. Lobbying can therefore be seen to diminish the gains from investment. In the parlance of the strategic investment literature (e.g., [16]), there is an incentive to adopt the "puppy dog" strategy – the firm underinvests to remain weak and inefficient in order to induce a less hostile response from the government. Thus, by credibly committing to less efficient technologies in earlier stages of the game, the polluter can rig in its favor the ensuing political equilibrium.

It is important to note that these results do not imply that environmental instruments, such as emission taxes, will be ineffective in controlling pollution.[vii] Instead the analysis suggests that when governments place a high value on political contributions, then stringent environmental regulations will be more successfully resisted by older and less efficient firms. The model therefore predicts that such industries will have greater success in securing policy concessions and support than other sectors.[viii] If, however, the government were indifferent to lobbyists and introduced stringent environmental controls, these regulations would have the usual effect of reducing environmental damage.

There is a substantial theoretical literature which examines the role of policy instruments on the incentives firms face to adopt new pollution abatement technologies. However, this work has neglected the role of lobbying on technology adoption.[ix] Similarly, the growing body of literature on rent seeking, deals with the effects of lobbying on the policy outcome, and has ignored the role of firm investment in a political equilibrium. This paper attempts to augment both the rent seeking and the environmental technology literature, by exploring the manner in which investment decisions can influence policy outcomes.

The remainder of this paper is organised as follows. Section 2 outlines the basic structure of the model, while section 3 derives the political equilibrium and describes the manner in which investment influences political contributions. Section 4 deals with the problem of investment and outlines the circumstances under which lobbying diminishes the incentive to invest in new technology. Section 5 discusses empirical issues, qualifications, extensions of the model and concludes the paper.

2. THE MODEL

We consider an economy with two sectors: a competitive numeraire sector and a monopoly which produces a polluting good. The demand side of the economy is modelled as in Singh and Vives [28]. There are two types of individuals in the economy. Consumers (C) who consume both the numeraire good and the monopolist's output. The utility function of the consumers is separable in the numeraire good[x]:

$$U^C = x^C + u(Q) - PQ \tag{1a}$$

where x^C is their consumption of the numeraire good, Q is output of the monopoly and P is the price of good Q. It is assumed that $\partial u/\partial Q > 0$ and $\partial^2 u/\partial Q^2 < 0$.

Production of good Q results in pollution emissions, denoted E, which adversely effect a subset of individuals termed environmentalists (en). The pollution damage suffered by environmentalists is defined by the damage function D(E), with $\partial D/\partial E > 0$ and $\partial^2 D/\partial E^2 > 0$. Environmentalists consume only the numeraire good and none of the polluting firm’s output, since they recognize the impact of their own consumption on pollution levels. The utility of the environmentalists is given by

$$U^{en} = x^{en} - D(E) \tag{1b}$$

From the demand function implied by (1a) we assume:

$$\frac{\partial P(Q)}{\partial Q} < 0 \tag{2}$$

As noted earlier, production of good Q results in pollution emissions. For simplicity we suppose that in the absence of pollution abatement, the emissions are proportional to output levels and defined by:

$$E^T = \theta Q, \qquad (3)$$

where $\theta > 0$, is the emission coefficient of output[xi].

The government levies a tax on pollution emissions at a rate t. As is well known, emission taxes provide firms with an incentive to abate emissions. Following Conrad [7] we assume that the cost function denoted $C(Q, c, v(a,\tau), t)$ contains three distinct components: *(i)* the production costs (c), *(ii)* the cost of abating emissions $v(a,\tau)$, which depends on the degree of abatement activity (a) and the type of pollution abatement equipment used (τ) and *(iii)* the tax paid on unabated emissions (t). The cost function is given by:

$$C(Q, c, v(a,\tau), t) = [c + (t(1 - a) + v(a,\tau)\, a)\theta]Q \qquad (4a)$$

Thus, $v(a,\tau)a\theta Q$ defines total abatement costs, while $(1 – a)t\theta Q$ is the emission tax burden. Section 4 describes the properties of the pollution abatement technology in more detail. However, at this stage we note that the technologies defined as $\tau \in [1, T]$, are distinguished by the fact that higher values of τ correspond to equipment with lower marginal and total abatement costs (i.e. $\partial v/\partial\tau < 0$). Hence, the abatement technologies with higher values of τ may be regarded as more cost effective and efficient. We further assume that $\partial v/\partial a > 0$, $\partial^2 v/\partial a^2 > 0$ and $\partial v/\partial\tau < 0$, $\partial^2 v/(\partial a\partial\tau) < 0$. Thus, pollution abatement costs rise with the degree of abatement at an increasing rate, and decline with more efficient technologies.

In an attempt to minimise its tax burden, the polluting firm offers political contributions S(t) to the government. These contributions are contingent upon the tax rate which is set by the government. Thus, profits are defined as[xii]:

$$\Pi = P(Q)Q - C(Q, c, v(a, \tau), t) - S(t) \qquad (4b)$$

To ensure that a unique maximum exists it is supposed that profits are strictly concave:

$$\partial^2\Pi/\partial Q^2 < 0 \qquad (4c)$$

We begin by solving the final stage of the game in which output levels are determined. Taking the tax and contribution schedules as given, equilibrium output is given by the solution to the first order condition:

$$P(Q) + \frac{\partial P}{\partial Q}Q - c = (t(1 - a) + v(a,\tau)a)\theta \qquad (4d)$$

Let Q^e denote the solution to (4d) in equilibrium.

Clearly, abatement levels will be chosen to minimise costs, given knowledge of the emission tax rate (t) and abatement costs (v(a,τ)). Thus, for a given level of output, the degree of abatement (a) is determined by the solution to:

$$\underset{a}{\text{Min}} \; C(Q,c, v(a,\tau),t) = [c + (t(1 - a) + v(a,\tau)\, a)\theta]Q \qquad (5a)$$

The associated first-order condition is:

$$\theta Q(\frac{\partial v}{\partial a}a + v - t) = 0 \qquad (5b)$$

Equation (5b) summarizes the familiar result that abatement will occur up to the point where the marginal abatement costs $(\frac{\partial v}{\partial a}a + v)$, equal the tax rate (t). Let a^e denote the solution to (5b). We note that with an emission tax of t, total pollution emissions are given by:

$$E(t) = (1 - a^e)\theta Q^e, \tag{5c}$$

while the corresponding level of total pollution abatement is:

$$A(t) = a^e \theta Q^e. \tag{5d}$$

For future reference, the following well known properties of the equilibrium are proved in the Appendix.

$$\frac{dQ^e}{dt} < 0 \tag{6a}$$

Equation (6a) reveals that higher taxes result in lower equilibrium output levels. This occurs because the tax raises production costs and induces the firm to reduce production levels.

In addition, higher emission taxes lead to an increase in the degree of abatement per unit of pollution:

$$\frac{da^e}{dt} > 0 \tag{6b}$$

Intuitively, an increase in the tax rate raises the costs of emitting pollution, and thus renders pollution abatement more attractive.

Finally, a rise in pollution abatement costs (v) leads to a decline in output levels, as a consequence of higher production costs:

$$\frac{dQ^e}{dv(a,\tau)} < 0. \tag{6c}$$

Equations (6a) and (6b) imply that higher emission taxes always lead to a decline in total emission levels. To see this, differentiate equation (5c) with respect to t:

$$\frac{dE(t)}{dt} = \theta(-Q^e \frac{da^e}{dt} + (1 - a^e)\frac{dQ^e}{dt}) < 0 \tag{6d}$$

The sign of (6d) follows from the fact that by (6b) $\frac{da^e}{dt} > 0$ and by (6a) $\frac{dQ^e}{dt} < 0$. For future reference we note that, since A(t) = $a^e\theta Q^e$ then equation (6d) may be rearranged and expressed as:

$$\frac{dE(t)}{dt} = = \theta\frac{dQ^e}{dt} - \theta\left(Q^e\frac{da^e}{dt} + a^e\frac{dQ^e}{dt}\right) = \theta\frac{dQ^e}{dt} - \frac{dA(t)}{dt} < 0 \tag{6e}$$

A necessary condition for $\frac{dE(t)}{dt} < 0$ is $\frac{dA(t)}{dt} = \theta\left(Q^e\frac{da^e}{dt} + a^e\frac{dQ^e}{dt}\right) > 0$, which implies that total abatement levels increase with higher taxes. This property is used in some of the proofs below.

3. THE POLITICAL EQUILIBRIUM

Having defined the equilibrium output and abatement levels, we now consider the manner in which political contributions are determined. The political contribution schedule offered by the firm is contingent on the tax rate chosen by the government (see [18]). The firm will choose its political contributions (S(t)) to maximise profits:

$$\underset{S(t)}{\text{Max}}\, \Pi(Q^e) = P(Q^e)Q^e - [c + (t(1 - a^e) + v(a^e,\tau)\, a^e)\theta]Q^e - S(t) \tag{7a}$$

The associated first-order condition is:

$$-(1 - a^e)\theta Q^e\frac{\partial t}{\partial S} - 1 = 0 \tag{7b}$$

The government is assumed to maximize a weighted sum of the political contributions it receives and aggregate social welfare. Social welfare gross-of contributions, is given by the sum of profits, consumers' surplus, pollution tax revenues and the damage suffered from pollution emissions:

$$W \equiv \int_0^Q P(Q)dQ - (c + v(a,\tau)a\theta + (1-a)\theta t)Q - D(E) + (1-a)\theta tQ \qquad (7c)$$

To ensure that a unique maximum exists it is supposed that $\partial^2 W/\partial Q^2 < 0$. For future reference the welfare maximizing level of output is defined as:

$$Q^* = \text{Argmax } W \qquad (7d)$$

Let $E^* = (1 - a^*)\theta Q^*$ be the associated level of pollution at the welfare maximising output level (Q^*). Let t^* be the emission tax required to achieve output level Q^* and define W^* as the resulting (maximal) level of welfare at Q^*.

Following Grossman and Helpman [18], the government is assumed to derive utility from lobby group contributions and social welfare. Specifically the government's objective function is given by a weighted sum of political contributions and social welfare.

$$G(t) = S(t) + \alpha W(t) \qquad (8a)$$

where α is the weight given to aggregate social welfare relative to political contributions ($S(t)$).

A subgame perfect Nash equilibrium for this game is a contribution schedule ($S(t)$) and a tax policy (t^L), such that: *(i)* the contribution schedule is feasible; (*ii*) the policy t^L maximizes the government's welfare, $G(t)$, taking the contribution schedule as given.

From Lemma 2 of Bernheim and Whinston [6] the following necessary conditions yield a subgame perfect Nash equilibrium $\{S, t^L\}$:

$$t^L \in \text{Argmax } G(t) = S(t) + \alpha W(t); \qquad (SI)$$

$$t^L \in \text{Argmax } \Pi(t) + G(t) \qquad (SII)$$

Condition (SI) asserts that the equilibrium tax t^L must maximize the government's payoff, given the contribution schedule offered. Condition (SII) requires that t^L must also maximize the joint payoff of the firm and the government. If this condition is not satisfied, the firm will have an incentive to alter its strategy to induce the government to change the tax rate, and capture close to all the surplus. Maximizing (SI) and (SII), and performing the appropriate substitutions, yields the equilibrium contribution schedule of the lobby group which satisfies:

$$\frac{\partial \Pi^G(t^L)}{\partial t} = \frac{\partial S(t^L)}{\partial t}. \qquad (8b)$$

where: $\Pi^G(t^L) = (P(Q^e)Q^e - C(Q^e, c, v(a^e, \tau), t^L))$, and $\frac{\partial \Pi^G(t^L)}{\partial t} = -(1 - a^e)\theta Q^e$

Equation (8b) reveals that in equilibrium, the change in the firm's political contribution (i.e. $\frac{\partial S(t^L)}{\partial t}$), equals the effect of the tax on its payoffs (i.e. $\frac{\partial \Pi^G(t^L)}{\partial t}$). Thus, as noted by Grossman and Helpman [18], the political contribution schedule is locally truthful. As in Bernheim and Whinston [6], this concept can be extended to a contribution schedule that is globally truthful. This yields a function which accurately represents the preferences of the lobbyist for all feasible t.

It is worth briefly outlining an important property of this equilibrium which has been frequently overlooked in the literature. Equation (7b) defines the profit maximising contributions of the firm. If the tax schedule is monotonic in contributions, then its inverse exists so that (7b) can be rearranged to yield:

$$-(1 - a^e)\theta Q^e = \frac{\partial S(t^L)}{\partial t} \qquad (8c)$$

Observe that (8c) is precisely the subgame perfect equilibrium condition of the political game which has been defined in equation (8b). This equivalence implies that the individually rational (Nash) contributions which maximise a firm's profits (i.e. (7b)), are equal to the contributions necessary for a subgame perfect equilibrium of the political game (i.e. (8b)). More significantly, it can be demonstrated that this result generalizes to the case of a lobby group with n > 1 firms. That is, if each firm takes the contribution levels of its rivals' as given, its Nash contribution will satisfy condition (8b). This implies that the subgame perfect political equilibrium does not require contributions from firms in a lobby group beyond the individually rational level. Thus lobbying is not constrained by free-riding in this model. [xiii]

Having determined the slope of the contribution schedule, it is necessary to derive an expression for the level of contributions in a political equilibrium. Grossman and Helpman demonstrate that with one lobby group, the equilibrium contribution to the government is defined by the difference in social welfare, when the emission tax is set at the welfare maximising rate t* and at the political equilibrium rate t^L. Specifically:

$$S(t^L) = \alpha(W^* - W^L) \tag{9}$$

Where: W* is the level of social welfare which eventuates when the tax is set at the welfare maximising rate t* and W^L is the level of social welfare when the tax is set at the political equilibrium rate t^L.

Observe that $\alpha(W^* - W^L)$ defines the loss of utility to the government when the tax rate deviates from the welfare maximising level. Equation (9) informs us that political contributions perfectly compensate the government for the welfare loss associated with participation of the lobby group in the political process. The welfare loss is weighted by the factor α in order to adjust for its importance in the government's objective function.

Having described the political equilibrium, we now examine the consequences of varying pollution abatement costs (v) on political contributions. Lemma 1 outlines the circumstances under which an increase in abatement costs results in lower political contributions.

***Lemma 1:* A*n increase in abatement costs induces the firm to lower its political contributions.*

$$\textit{(i.e. } \frac{dS(t^L)}{dv(a,\tau)} < 0\textit{).}$$

Proof*: See Appendix*

This result reflects the fact that an increase in abatement costs makes pollution control more difficult and therefore undermines the government's ability to limit emissions. Since a given tax now yields a smaller benefit to the government, the polluter needs to spend less on lobbying and political contributions decline.

Having determined the impact of abatement costs on contributions, we explore the effects of varying abatement costs on the tax rate in a political equilibrium. The result is summarised in Proposition 1.

PROPOSITION 1*: An increase in abatement costs leads to a lower emission tax being set in the political equilibrium.*

$$\textit{(i.e. } \frac{dt^L}{dv(a,\tau)} < 0\textit{).}$$

Proof**:** By condition (SI) $t^L \in$ Argmax G = S + αW. This implies that t^L solves the first order condition:

$$\frac{\partial S}{\partial t} + \alpha \frac{\partial W}{\partial t} = 0 \qquad \text{(I)}$$

Let W^L denote the corresponding level of social welfare at the political equilibrium tax rate t^L. Totally differentiating (I):

$$\left(\frac{\partial^2 G}{\partial t^2}\right) dt^L + \left(\frac{\partial^2 G}{\partial t \partial v}\right) dv = 0 \qquad \text{(II)}$$

Rearrange:

$$\frac{dt^L}{dv} = \frac{-(\partial^2 G/(\partial t \partial v))}{(\partial^2 G/\partial t^2)} \qquad \text{(III)}$$

It is assumed that $\left(\frac{\partial^2 G}{\partial t^2}\right) < 0$ (for a unique maximum). It follows that Sign $\left(\frac{dt^L}{dv}\right)$ = Sign $\left(\frac{\partial^2 G}{\partial t \partial v}\right)$. By Young's Theorem: $\left(\frac{\partial^2 G}{\partial t \partial v}\right) = \left(\frac{\partial^2 G}{\partial v \partial t}\right)$. Thus:

$$\frac{\partial G}{\partial v} = \frac{\partial S}{\partial v} + \alpha \frac{\partial W^L}{\partial v} \qquad \text{(IV)}$$

But by (9) $S = \alpha(W^* - W^L)$. Substituting (9) in (IV):

$$\frac{\partial G}{\partial v} = \alpha \frac{\partial W^*}{\partial v} \qquad \text{(V)}$$

Differentiating W with respect to v in (7c):

$$\frac{\partial G}{\partial v} = \alpha \frac{\partial W^*}{\partial v} = -\alpha a^* \theta Q^* = -\alpha A^* \qquad \text{(VI)}$$

where $A^* = a^*\theta Q^*$

Thus:

$$\frac{\partial^2 G}{\partial v \partial t} = -\alpha \frac{\partial A^*}{\partial t} < 0 \quad \left(\text{since } \frac{\partial A}{\partial t} > 0\right) \qquad \text{(VII)}$$

Hence : $\frac{dt^L}{dv} < 0.$

Intuitively, this result may be explained as follows. From equation (8b) we know that political donations are truthful, in the sense that they reflect the change in the firm's payoffs which results from a change in the tax rate. An increase in abatement costs makes pollution control more expensive for the firm. Thus, as abatement costs rise, profits and political contributions tend to fall. A government which values political donations, has an incentive to adopt policies which mitigate the decline in profits and political donations. To maintain contribution levels, the government therefore lowers the emission tax rate.

This result has important policy implications. It suggests that, if firms can credibly commit to higher abatement costs in earlier stages of the game, they can potentially rig in their own favour the policy outcome in the ensuing political equilibrium. The next Section deals with the circumstances in which technology can be used as a credible commitment device.

4. TECHNOLOGY CHOICE

Having explored the impact of abatement costs on contribution levels, this Section investigates the manner in which political lobbying influences the firm's choice of pollution abatement technology. We begin by defining the properties of the available pollution abatement technologies.

Let $\tau \in [1, T] \subset \Re_+$ be the continuum of existing pollution abatement technologies. The technologies in τ are distinguished by their associated abatement costs. Specifically, there exists a one-to-one mapping from the set of technologies (τ) to the abatement costs associated with each technology ($v(a, \tau)$). It is assumed that $\frac{\partial v(a,\tau)}{\partial \tau} < 0$, $\frac{\partial^2 v(a,\tau)}{\partial \tau^2} < 0$ and that $\frac{\partial^2 v(a,\tau)}{\partial a \partial \tau} < 0$. Thus, the technologies in τ are ranked in terms of their efficiency. They are identified by the fact that higher values of τ correspond to equipment which embodies lower total and marginal abatement costs. The cost of purchasing equipment associated with a given technology of type $\tau \in [1, T]$ is given by $K(\tau)$. It is assumed that $K(\tau)$ is a sunk cost and that $\frac{\partial K(\tau)}{\partial \tau} > 0$, $\frac{\partial^2 K(\tau)}{\partial \tau^2} > 0$. This implies that the efficient technologies, which abate pollution more cheaply, are more expensive to purchase.

For future reference we note that totally differentiating abatement costs $v(a,\tau)$, with respect to τ yields:

$$\frac{dv(a,\tau)}{d\tau} = \frac{\partial v}{\partial \tau} + \frac{\partial v}{\partial a}\frac{\partial a}{\partial t}\frac{\partial t}{\partial \tau} \tag{10}$$

The sign of equation (10) is ambiguous. In what follows, we assume that $\frac{dv(a,\tau)}{d\tau} < 0$ and $\frac{d^2v(a,\tau)}{d\tau^2} < 0$. This ensures that greater investment in technology always lowers overall pollution abatement costs, so that even with lobbying there is a strong (abatement cost saving) motive to invest in cleaner technologies.[xiv]

The firm will choose a type of pollution abatement technology (τ) to maximise profits. Thus:

$$\underset{\tau}{\text{Max}} \quad \hat{\Pi} = (P(Q^e) - c - v(a^e,\tau)a^e\theta - (1-a^e)\theta t)Q^e - S(t) - K(\tau) \qquad (11a)$$

The first order condition is:[xv]

$$\frac{\partial K(\tau)}{\partial \tau} = -a^e\theta Q^e \frac{\partial v(a^e,\tau)}{\partial \tau} - \frac{dS}{dv(a^e,\tau)}\frac{\partial v(a^e,\tau)}{\partial \tau} \qquad (11b)$$

The firm will acquire the type of equipment (τ) at which the marginal cost of purchasing a more efficient technology ($\frac{\partial K(\tau)}{\partial \tau}$) is set equal to: *(i)* the marginal benefits (in the form of cost savings) from this technology ($a^e\theta Q^e \frac{\partial v(a^e,\tau)}{\partial \tau}$) and *(ii)* the benefits which arise from the need to lobby less as v rises ($\frac{dS}{dv(a^e,\tau)}\frac{\partial v(a^e,\tau)}{\partial \tau}$). Lobbying and the choice of technology are therefore substitutes in the firm's profit function.[xvi] Observe that in the absence of lobbying firms would simply equate the marginal cost of acquiring a more efficient technology to the marginal benefits (in the form of cost savings) from the equipment. This suggests that lobbying may induce firms to underinvest in pollution abatement technology. The circumstances under which this occurs are summarised with greater accuracy in the following Proposition.

Define the choice of technology under lobbying as:

$$\tau^{L} \in \text{Arg max}\,\hat{\Pi} \;\; \equiv (P(Q^{L}) - c - v(a^{L}, \tau^{L})a^{L}\theta - (1-a^{L})\theta t^{L})Q^{L} - S(t^{L}) - K(\tau^{L})$$

Where: $Q^{L} = Q(\tau^{L}, t^{L})$; $a^{L} = a(\tau^{L}, t^{L})$

Define the choice of technology in the absence of lobbying as:

$$\tilde{\tau} \in \text{Arg max}\,\tilde{\Pi} \equiv (P(\tilde{Q}) - c - v(\tilde{a}, \tilde{\tau})\tilde{a}\theta - (1-\tilde{a})\theta t)\tilde{Q} - K(\tilde{\tau})$$

Where: $\tilde{Q} = Q(\tilde{\tau}, t), \tilde{a} = a(\tilde{\tau}, t)$

PROPOSITION 2*: If the abatement costs associated with less efficient technologies are sufficiently high, then lobbying lowers the level of investment in pollution abatement technology.*

(i.e. $\tau^{L} < \tilde{\tau}$ *if* $\left(a^{L}\theta Q^{L}\frac{\partial v(a^{L}, \tau^{L})}{\partial \tau}\right) > \left(\theta\tilde{Q}\left(\tilde{a}\frac{\partial v(\tilde{a}, \tilde{\tau})}{\partial \tau} + (1-\tilde{a})\frac{\partial t}{\partial \tau}\right)\right)$*).*

Proof: The first order condition when there is no lobbying is given by:

$$\frac{\partial K(\tilde{\tau})}{\partial \tau} = -\tilde{a}\theta\tilde{Q}\frac{\partial v(\tilde{a}, \tilde{\tau})}{\partial \tau} - (1-\tilde{a})\theta\tilde{Q}\frac{\partial t}{\partial \tau} \qquad \text{(I)}$$

When firms lobby from equation (11b) the associated first order condition is:

$$\frac{\partial K(\tau^{L})}{\partial \tau} = -\frac{dS}{dv(a, \tau)}\frac{\partial v(a^{L}, \tau^{L})}{\partial \tau} - a^{L}\theta Q^{L}\frac{\partial v(a^{L}, \tau^{L})}{\partial \tau} \qquad \text{(II)}$$

Suppose that $\tilde{\tau} > \tau^{L}$, then $\frac{\partial K(\tilde{\tau})}{\partial \tau} > \frac{\partial K(\tau^{L})}{\partial \tau}$ (since by assumption $\frac{\partial K(\tau)}{\partial \tau}>0$, $\frac{\partial^{2} K(\tau)}{\partial \tau^{2}}>0$). Thus the FOCs in (I) and (II) will be satisfied when the right hand side of (II) is less than that of (I). That is:

$$-\frac{dS^{d}}{dv(a, \tau)}\frac{\partial v(a^{L}, \tau^{L})}{\partial \tau} - a^{L}\theta Q^{L}\frac{\partial v(a^{L}, \tau^{L})}{\partial \tau} < -\tilde{a}\theta\tilde{Q}\frac{\partial v(\tilde{a}, \tilde{\tau})}{\partial \tau} - (1-\tilde{a})\theta\tilde{Q}\frac{\partial t}{\partial \tau} \qquad \text{(III)}$$

Since $\frac{\partial v(a, \tau)}{\partial \tau} < 0$ and $\frac{dS}{dv(a, \tau)} < 0$, then, $-\frac{dS}{dv(a, \tau)}\frac{\partial v(a^{L}, \tau^{L})}{\partial \tau} < 0$. It follows that condition (III) is satisfied when:

$$a^{L}\theta Q^{L}\frac{\partial v(a^{L}, \tau^{L})}{\partial \tau} > \theta\tilde{Q}\left(\tilde{a}\frac{\partial v(\tilde{a}, \tilde{\tau})}{\partial \tau} + (1-\tilde{a})\frac{\partial t}{\partial \tau}\right) \qquad \text{(IV)}$$

Proposition 2 formalises the natural condition that underinvestment in technology acts as a credible commitment device, if less efficient technologies are associated with sufficiently high abatement costs. When this condition is satisfied, underinvestment provides a credible signal to the government that more stringent environmental regulations will result in lower profits. Since political contributions are linked to profits, a decline in profits leads to a fall in political donations. A government which values political contributions is therefore induced to adopt a more favourable policy towards firms.

In a sequential game, lobbying leads to sub-optimal levels of investment for two distinct reasons. Firstly as noted earlier, political contributions and technology choice are substitutes in the profit function. Thus, any positive level of lobbying will necessarily lead to a decline in investment. More importantly, in a sequential game investment also acts as a credible commitment device, which induces a further reduction in investment.[xvii] In order to isolate the commitment component of underinvestment, we compare the investment level in a game when technology and contributions are simultaneously chosen, with investment levels in a sequential game when technology is chosen first and contributions later (as in the present model). The commitment effect is then given by the difference in investment in a sequential game as defined in equation (11b) (τ^L), and that in a simultaneous game (denoted τ^i).

We begin by defining the equilibrium when contributions and technology choice are simultaneously determined by the firm. In a simultaneous game, equilibrium contributions and technology levels are given by the solution to:

$$\underset{S(t),\tau}{\mathrm{Max}} \quad \Pi^i = (P(Q) - c - v(a,\tau)a\theta - (1-a)\theta t)Q - S(t) - K(\tau) \qquad (12a)$$

The first-order conditions are:

$$-(1-a^i)\theta\frac{\partial t^i}{\partial S}Q^i-1=0 \qquad (12b)$$

$$-a^i\theta Q^i\frac{\partial v(a^i,\tau^i)}{\partial \tau}-\frac{\partial S^i}{\partial t}\frac{\partial t^i}{\partial v}\frac{\partial v^i}{\partial \tau}-\frac{\partial K(\tau^i)}{\partial \tau}=0 \qquad (12c)$$

where superscript i denotes terms in the simultaneous equilibrium

Let $S^i(t)$, τ^i denote the solutions to the system in (12b) and (12c).

PROPOSITION 3*: The level of investment in abatement technology in a sequential game (τ^L), is less than the level of investment in abatement technology in a simultaneous game (τ^i).*

(i.e (τ^L - τ^i) < 0).

Proof*: See Appendix.*

Proposition 3 reveals that there is less investment when technology and lobbying are determined sequentially, than when they are chosen simultaneously. This reflects the first mover advantage in a sequential game which allows the firm to use investment as a commitment device. Underinvestment in the first stage of the game provides a credible signal to the government that higher taxes will result in lower profits and a fall in political contributions. A government which values political donations is thus deterred from raising emission taxes. In the parlance of Fudenberg and Tirole [16] the firm adopts the “puppy dog” strategy: it underinvests in abatement technology in order to induce a less hostile reaction in succeeding stages of the game.

Finally for completeness, we compare the level of investment in a sequential game with the welfare maximising level of investment. Recall that welfare is defined as the sum of: profits, consumers’ surplus, pollution tax revenues and the damage suffered from pollution emissions. Consider a situation where technology levels are chosen to maximise welfare. In the Appendix it is demonstrated that the welfare maximising level of investment satisfies the first-order condition:

$$-a^*\theta Q^*\left(\frac{\partial v^*}{\partial \tau}+\frac{t^*}{a^*}\frac{da^*}{d\tau}\right)=\frac{\partial K(\tau^*)}{\partial \tau} \qquad (13)$$

where * is used to denote terms in the welfare maximising equilibrium

Let τ^* be the solution to (13).

Proposition 4 *If abatement costs associated with less efficient technologies are sufficiently high, then the welfare maximising level of investment (τ*) exceeds the level of investment undertaken by a private firm in the sequential lobbying equilibrium (τ^L).*

(i.e. $\tau^* > \tau^L$ *if* $a^L\theta Q^L\frac{\partial v^L}{\partial \tau}-a^*\theta Q^*\frac{\partial v^*}{\partial \tau}>\frac{t^*}{a^*}\frac{da^*}{d\tau}-\frac{dS(t^L)}{dv}\frac{\partial v^L}{\partial \tau}$*)*

Proof*: See Appendix*

Proposition 4 summarises the usual condition that if abatement costs decline sufficiently with investment, then investment levels in the welfare maximising equilibrium exceed those in the lobbying equilibrium.[xviii]

These results have significant implications for environmental control. They suggest that there exist circumstances in which firms have an incentive to eschew more efficient technologies in order to obtain greater policy concessions.

5. IMPLICATIONS AND CONCLUSIONS

Encouraging the adoption of advanced pollution abatement technology is an important environmental policy objective. However, the existing literature appears to have neglected the effects of lobbying on the choice of technology. Accordingly, this paper has attempted to examine the manner in which political factors influence investment decisions. The central message is that when governments are receptive to special interest group pressures, political considerations may provide an incentive for firms to reject cost saving investments in pollution abatement. If abatement costs are sufficiently high, underinvestment in new abatement technology provides a credible signal to the government that profits and political donations will decline if stringent environmental taxes are introduced. A government which values political contributions is therefore induced to adopt a more favourable policy towards firms. Hence, industries with older and more polluting technologies are better placed to secure policy concessions.

While the analysis in this paper has been conducted in terms of an emission tax, the results apply to other regulatory instruments which increase the costs of emissions. Any policy which makes pollution more expensive for the firm, will induce underinvestment in technology if the government is known to be receptive to special interest groups. This occurs because underinvestment credibly signals to the government that more stringent regulations will lead to a decline in political donations. It is important to note that these results simply indicate that less efficient industries may be more successful in securing concessions if abatement costs are sufficiently high. The analysis does not suggest that stringent regulatory policies, if introduced, will be ineffective in controlling pollution.

The model can also be applied to other forms of lobbying. An issue which has received considerable attention in recent years is the success of declining industries in securing trade protection and income support (see Baldwin [4], Grossman and Helpman ([19]). Our analysis suggests that by remaining technologically inefficient, these industries can raise the welfare costs of reform, and are thus able to lobby more effectively for protection.

The mechanisms outlined in this paper are new and have therefore not been statistically validated. Direct empirical tests would necessitate analyzing the effects of investment, lobbying and pollution intensity on the stringency of environmental policy. In the absence of such econometric work, there is only *indirect* support for the predictions of this model from studies that have examined other hypotheses. For instance, the growing empirical literature on trade protection suggests that older "rust belt" industries receive greater protection and support than do the less polluting "sunrise" industries in developed economies. Many of these older industries tend to be highly polluting and include: metals, chemicals and mineral products (Mani and Wheeler [25] classify these as amongst the most pollution intensive). [xix] In a more direct test of pollution intensive industries and trade protection in LDCs, Hettige et al [20] find that countries with more toxic intensive manufacturing sectors, provide greater protection to these industries. These findings are consistent with the conclusions of this model that more polluting industries often garner greater policy concessions.

Further indirect statistical support for the results are provided by Eliste and Fredriksson [14] in an econometric study of environmental policy in the agricultural sector. They find that the greater is the impact of the environmental degradation variables, the higher is the level of government compensation, which neutralizes the effects of more stringent environmental regulations. Eliste and Fredriksson interpret their results as implying that high polluters obtain greater support through more effective lobbying. The authors conclude that:

> *"One possibility of our results is that the combination of environmental policies and associated transfers* ***may*** *in the aggregate worsen environmental quality…"*

This finding also appears to accord with a central implication of the model that high polluters may receive favourable treatment. Others support for the model can be found in case studies. For instance, Leidy and Hoekman [23] provide examples of industries in the USA and EU with high pollution abatement costs, which have sought and obtained greater trade protection. While none of these studies provide a *direct* statistical test of the *mechanisms* outlined in this paper, the evidence appears to be broadly consistent with the central predictions. What remains to be tested in future empirical research is the role of investment and lobbying on the degree of regulation.

There are a number of other important issues that have not been considered. The results in this paper depend critically on the assumed sequence of events. The credible commitment effects stem from the assumption that firms determine their investment first and the government chooses its policy taking the investment decision as given. This seems reasonable if it is supposed that investment in technology is a long run decision variable, while the details of government policies are influenced by lobby group pressures and more immediate (short term) political concerns[xx]. If, however, firms delay their investment decisions so that the sequence of events is reversed, then investment can no longer have a credible commitment effect. Clearly, delaying investments would be the rational strategy for firms which confront a government which is not receptive to special interest group pressures. Similarly, postponing investment would also be rational for a firm if there is considerable uncertainty about the government's responses and the payoffs from lobbying. Formally, this could be modeled as a signaling game in which the government's "type" is not known to the lobbyists. Whether firms precommit to technology, or choose to postpone investment, is an issue which is perhaps best resolved empirically. The present model predicts that where a government is known to be receptive to interest group lobbying, precommitment would be the optimal strategy. Thus, an empirical test of the timing of investment and policy decisions may provide some evidence of a government's receptiveness to lobby group pressures.[xxi]

Another issue which has been ignored is the public good aspect of investment in an industry lobby group.[xxii] If there is more than one firm in the lobby group, it is possible that underinvestment may have credible commitment value only if most firms in the lobby group eschew the efficient technologies. In this situation, it could pay each firm to defect and invest in cleaner technology, so long as its rivals do not. The defecting firm would thus benefit from the lower tax, without contributing to it through underinvestment. In this situation, the underinvestment equilibrium could be sustained in one of two ways. First, as is well known, if firms in the lobby group interact over an indefinite period of time, various forms of cooperation (e.g. underinvestment) can be sustained if discount rates are sufficiently low. However, in a finite period game, the underinvestment equilibrium could be sustained through the local truthfulness property of the political equilibrium. Recall that each firm donates to the government the "locally truthful" contribution. Thus, firms which adopt cleaner technologies are less affected by a pollution tax, and by "local truthfulness" will contribute less to the government. Since the "clean" firms contribute less, in equilibrium they receive fewer concessions. In essence, these "clean "firms represent a different lobby group to those who underinvest and they therefore receive a different set of policy concessions. However, this equilibrium which involves asymmetric firms raises a number of complex and interesting modeling issues which warrant further research.

APPENDIX[xxiii]

Equation 6a

From equation (4d) we know that in equilibrium Q^e solves the first-order condition:

$$\frac{\partial \Pi}{\partial Q} = \frac{\partial P}{\partial Q} Q^e + P(Q^e) - c - va\theta - (1-a)\theta t = 0 \tag{A1}$$

Totally differentiating:

$$(\partial^2 \Pi / \partial Q^2) dQ^e - (1-a)\theta dt = 0 \tag{A2}$$

where: $\frac{\partial^2 \Pi}{\partial Q^2} = Q\frac{\partial^2 P}{\partial Q^2} + 2\frac{\partial P}{\partial Q} < 0$ (by equation (4c))

Rearranging:

$$\frac{dQ^e}{dt} = \frac{(1-a)\theta}{\partial^2 \Pi^i / \partial Q^2} \quad < 0 \tag{A3}$$

The sign of (A3) follows from the fact that the denominator is negative by (4c) and $(1 - a)\theta > 0$.

Equation 6b

From equation (5b) in equilibrium, a^e solves the first-order condition:

$$\frac{\partial C}{\partial a} = \theta Q(\frac{\partial v}{\partial a} a^e + v - t) = 0 \tag{A4}$$

Totally differentiating:

$$(\partial^2 C / \partial a^2) da^e - \theta Q dt = 0 \tag{A5}$$

where: $$\frac{\partial^2 C}{\partial a^2} = \theta Q(2\frac{\partial v}{\partial a} + a\frac{\partial^2 v}{\partial a^2}) > 0 \tag{A6}$$

The sign of (A6) follows from the assumptions that $\frac{\partial v}{\partial a} > 0, \frac{\partial^2 v}{\partial a^2} > 0$.

Rearranging:

$$\frac{da^e}{dt} = \frac{\theta Q}{\partial^2 C / \partial a^2} \quad > 0 \tag{A7}$$

The sign of (A7) follows from the fact that $\partial^2 C / \partial a^2 > 0$ and $\theta Q > 0$.

Equation 6c

Similarly totally differentiating the first-order condition (4d):

$$(\partial^2 \Pi / \partial Q^2) dQ^e - a^e \theta dv = 0 \tag{A8}$$

Rearranging:

$$\frac{dQ^e}{dv} = \frac{a\theta}{\partial^2 \Pi / \partial Q^2} \quad < 0. \tag{A9}$$

The sign of (A9) follows from the fact that the denominator is negative by (4c) and $a\theta > 0$.

Lemma 1:

From (7c) welfare is given by:

$$W \equiv \int_0^Q P(Q)dQ - (c + v(a,\tau)a\theta + (1-a)\theta t)Q - D(E) + (1-a)\theta tQ \tag{A10}$$

Differentiating with respect to v:

$$\frac{dW}{dv} = \frac{dW}{dQ}\frac{dQ}{dv} + \frac{\partial W}{\partial v} \tag{A11}$$

$$= \frac{dW}{dQ}\frac{dQ}{dv} - a\theta Q \tag{A12}$$

By definition, at the welfare maximising output level Q* the following first-order condition holds:

$$\frac{dW^*}{dQ} = 0 \tag{A13}$$

Thus, at the welfare maximising output level Q*:

$$\frac{dW^*}{dv} = -a^*\theta Q^* \tag{A14}$$

From equation (9), S = $\alpha(W^* - W^L)$. Differentiating S with respect to v, using (A12) and (A14):

$$\frac{dS}{dv} = \alpha(-a^*\theta Q^* - (\frac{dW^L}{dQ}\frac{dQ^L}{dv} - a^L\theta Q^L)) \tag{A15}$$

Rearranging, using the fact that A = aθQ:

$$\frac{dS}{dv} = \alpha((A^L - A^*) - (\frac{dW^L}{dQ}\frac{dQ^L}{dv})) \tag{A16}$$

Since $\frac{dA}{dt} > 0$, and $t^* > t^L$, it follows that $A^* > A^L$. Hence $(A^L - A^*) < 0$.

We now show that $(\frac{dW^L}{dQ}\frac{dQ^L}{dv}) > 0$. From (6a) we know that, $\frac{dQ}{dt} < 0$, and $t^* > t^L$ thus $Q^* < Q^L$. Since (*i*) by definition $\frac{dW^*}{dQ} = 0$, (*ii*) it has been shown that $Q^* < Q^L$, and (*iii*) by assumption $\frac{d^2W}{dQ^2} < 0$, it follows that $\frac{dW^L}{dQ} < 0$. Thus $(\frac{dW^L}{dQ}\frac{dQ^L}{dv}) > 0$ (since $\frac{dQ^L}{dv} < 0$ by (6c)). Hence $\frac{dS}{dv} < 0$.

Proposition 3

In a simultaneous equilibrium the levels of lobbying and technology are defined by the solution to (12b) and (12c) reproduced here as (A17) and (A18):

$$-(1-a^i)\theta\frac{\partial t^i}{\partial S}Q^i - 1 = 0 \tag{A17}$$

$$-a^i\theta Q^i\frac{\partial v^i}{\partial \tau} - \frac{\partial S^i}{\partial t}\frac{\partial t^i}{\partial v}\frac{\partial v^i}{\partial \tau} - \frac{\partial K^i(\tau)}{\partial \tau} = 0 \tag{A18}$$

where superscript i is used to identify terms in the simultaneous equilibrium. Rearranging and substituting (A17) into (A18):

$$-a^i\theta Q^i\frac{\partial v^i}{\partial \tau} + (1-a^i)\theta Q^i\frac{\partial t}{\partial v}\frac{\partial v^i}{\partial \tau} = \frac{\partial K^i(\tau)}{\partial \tau} \tag{A19}$$

Let τ^i denote the solution in the simultaneous equilibrium. Let τ^L be the solution in sequential game as defined in equation (11b).

Suppose that $\tau^L \geq \tau^i$. Since $\frac{\partial K(\tau)}{\partial \tau} > 0$, $\frac{\partial^2 K(\tau)}{\partial \tau^2} > 0$ (11b) and (A19) imply that:

$$\frac{\partial K(\tau^L)}{\partial \tau} \geq \frac{\partial K^i(\tau^i)}{\partial \tau} \tag{A20}$$

For (A20) to hold requires that:

$$-a^L\theta Q^L \frac{\partial v^L}{\partial \tau} - \frac{dS}{dv}\frac{\partial v^L}{\partial \tau} \geq -a^i\theta Q^i \frac{\partial v^i}{\partial \tau} + (1-a^i)\theta Q^i \frac{\partial t}{\partial v}\frac{\partial v^i}{\partial \tau} \tag{A21}$$

However, $-\frac{dS}{dv}\frac{\partial v^L}{\partial \tau} < 0$ (since $\frac{dS}{dv} < 0, \frac{\partial v^L}{\partial \tau} < 0$) and $(1-a^i)\theta Q^i \frac{\partial t}{\partial v}\frac{\partial v^i}{\partial \tau} > 0$ (since $\frac{\partial t}{\partial v} < 0, \frac{\partial v^i}{\partial \tau} < 0$) Thus:

$$-\frac{dS}{dv}\frac{\partial v^L}{\partial \tau} < 0 < (1-a^i)\theta Q^i \frac{\partial t}{\partial v}\frac{\partial v^i}{\partial \tau} \tag{A22}$$

It follows that a necessary condition for (A21) to hold is:

$$-A^i \frac{\partial v^i}{\partial \tau} < -A^L \frac{\partial v^L}{\partial \tau} \tag{A23}$$

where $A^k = a^k\theta Q^k$ ($k = i, L$).

We now show that (A23) cannot hold. First, note that differentiating A^k with respect to τ:

$$\frac{dA^k}{d\tau} = \theta Q^k \frac{da^k}{d\tau} + a\theta \frac{dQ^k}{d\tau} > 0 \quad (k = i, L) \tag{A24}$$

The sign of (A24) follows from the fact that: (*i*) $\frac{dQ^k}{d\tau} = \frac{dQ^k}{dv}\frac{dv^k}{d\tau} > 0$ (since $\frac{dQ^k}{dv} < 0$ by equation (6c), $\frac{dv^k}{d\tau} < 0$ by assumption) and (*ii*) $\frac{da^k}{d\tau} > 0$.[xxiv]

Since $\frac{dA}{d\tau} > 0$ and $\tau^L \geq \tau^i$ then $A^L \geq A^i$. Thus:

$$-A^L \leq -A^i \tag{A25'}$$

It has been assumed that $\frac{\partial v}{\partial \tau} < 0$ and $\frac{\partial^2 v}{\partial \tau^2} < 0$. Since $\tau^L \geq \tau^i$, then:

$$0 > \frac{\partial v^i}{\partial \tau} \geq \frac{\partial v^L}{\partial \tau} \tag{A25''}$$

(A25') and (A25") imply that:

$$-A^i \frac{\partial v^i}{\partial \tau} \geq -A^L \frac{\partial v^L}{\partial \tau} \tag{A26}$$

However, (A26) contradicts the necessary condition in (A23). Thus $\tau^L < \tau^i$.

Proposition 4

Welfare is defined as:

$$W \equiv \int_0^Q P(Q)dQ - (c + v(a,\tau)a\theta + (1-a)\theta t)Q - D(E) + (1-a)\theta tQ \ - K(\tau)$$

$$= \int_0^Q P(Q)dQ - (c + av(a,\tau)\theta)Q - D(E) - K(\tau) \qquad \text{(A27)}$$

The welfare maximising tax rate and level of investment satisfy the first-order conditions:

$$\frac{dW}{dt} = \frac{\partial W}{\partial Q}\frac{\partial Q}{\partial t} = 0 \qquad \text{(A28')}$$

$$\frac{dW}{d\tau} = \frac{\partial W}{\partial Q}\frac{\partial Q}{\partial \tau} + \frac{\partial W}{\partial v}\frac{\partial v}{\partial \tau} + \frac{\partial W}{\partial a}\frac{\partial a}{\partial \tau} + \frac{\partial W}{\partial \tau} = 0 \qquad \text{(A28'')}$$

Since $\partial Q/\partial t \neq 0$ (by 6a), it follows that $\partial W/\partial Q = 0$. Using (A28') and(5b), (A28") simplifies to:

$$-a^*Q^*\theta\left(\frac{\partial v^*}{\partial \tau} + \frac{t^*}{a^*}\frac{\partial a^*}{\partial \tau}\right) = \frac{\partial K(\tau^*)}{\partial \tau} \qquad \text{(A29)}$$

Note that $\tau^* > \tau^L$ if $\frac{\partial K(\tau^*)}{\partial \tau} > \frac{\partial K(\tau^L)}{\partial \tau}$. Using (11b) and (A29), this requires that:

$$-a^*\theta Q^*\frac{\partial v^*}{\partial \tau} + a^L\theta Q^L\frac{\partial v^L}{\partial \tau} > \frac{t^*}{a^*}\frac{da^*}{d\tau} - \frac{dS(t^L)}{dv}\frac{\partial v^L}{\partial \tau} \qquad \text{(A30)}$$

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ENDNOTES

[i] ElAgraa [13] provides evidence based on inter industry studies. Some industry specific examples are: textiles (Dixit and Londregan [11]) and agriculture (Anderson [2]).

[ii] For example, by 1980 a sizeable proportion (84%) of the US steel industry continued to employ the open-hearth furnace (based on 19^{th} century technology), two decades after Japanese firms had adopted the energy efficient, continuous casting techniques (Dertouzos *et al* [10]). Other cases of the slow adoption of cost saving environmental technologies are provided in DeCanio [6], Parkinson [26],and Dorfman *et al* [12]. A more extreme, and perhaps less typical, example is that of the timber industry where logging operators in Indonesia constructed tracks through pristine forests, even where existing roads provided a cheaper and more direct route to the saw mills (Rainforest News (June, 1996)).

[iii] For simplicity, the analysis focuses on a monopoly. However, the results generalize to the case of a polluting oligopoly.

[iv] Since the focus of the Grossman Helpman model is on the short run determinants of policy, it is assumed that the incumbent government sets its policy, taking as given the capital stock (investment decision) of the firm, which is assumed to be a long run decision variable.

[v] It is assumed that capital costs are sunk.

[vi] Recall that a profit maximising firm abates pollution up to the point where the marginal abatement cost equals the tax rate. As marginal abatement costs rise firms abate less pollution per unit of output.

[vii] I am grateful to a referee for emphasizing the significance of this issue.

[viii] As noted by a referee, this may partly explain the relatively low energy prices in some economies such as the USA and the slow adoption of energy saving technology in certain energy intensive sectors.

[ix] For a recent example see Jung *et al* [22].

[x] This formulation implies that we can ignore income effects and perform partial equilibrium analysis.

[xi] The main conclusions hold so long as pollution is convex in output levels. However, a more general pollution technology function considerably complicates the proofs.

[xii] As in Grossman and Helpman (*op cit*) for expositional ease we separate lobbying costs from production costs in the profit function.

[xiii] Free-riding does not prevent lobbying in the model because the political equilibrium is sustained by the profit maximising (Nash) contributions of each firm. With the exception of Goldberg and Maggi [17], this issue appears to have been overlooked in the literature and it has generally been assumed that lobbying can be undermined by free-riding in this model. Moreover, the political equilibrium is identical whether the lobbyists are assumed to be "groups" representing an entire industry or simply the firms acting individually. Intuitively, this follows directly from the local truthfulness condition (8b). For formal proofs see Damania [8]. If, however, there are fixed costs associated with lobbying, and there is more than one firm who shares these costs, the problem becomes similar to that of the private provision of a discrete public good. Since the focus of this paper is on strategic investment issues rather than free-riding in lobby groups, these important issues are ignored for brevity.

[xiv] Eschewing this assumption does not alter the results, but does appear to weaken the argument for underinvestment. That is, if more investment does not always lower abatement costs, firms may have little reason to acquire cleaner technologies.

[xv] By the envelope theorem we can ignore the indirect effect of τ on profits through changes in output and abatement levels. That is: $(\partial\Pi/\partial Q)(\partial Q/\partial v)(\partial v/\partial\tau) = 0$ since $(\partial\Pi/\partial Q) = 0$, similarly $(\partial\Pi/\partial a)(\partial a/\partial\tau) = 0$ since equation (5b) implies that $(\partial\Pi/\partial a) = -(\partial C/\partial a) = 0$. Thus differentiation of (11a) yields: $a^e\theta Q^e\frac{\partial v}{\partial\tau} - \frac{\partial S}{\partial v}\frac{\partial v}{\partial\tau} - \frac{\partial S}{\partial t}\frac{\partial t}{\partial v}\frac{\partial v}{\partial\tau} - (1-a)\theta Q^e\frac{\partial t}{\partial v}\frac{\partial v}{\partial\tau} - \frac{\partial K}{\partial\tau} = 0$. However, from equation (8b) we know that: $\frac{\partial S}{\partial t} = -(1-a)\theta Q$. Using this result, yields the first order condition in (11b).

[xvi] I am grateful to an anonymous referee for emphasizing the relevance of this relationship.

[xvii] Recall that underinvestment credibly signals to the government that political contributions will decline with higher taxes.

[xviii] So long as $\tau^* \neq \tau^L$ welfare will always be lower in the lobbying equilibrium.

[xix] Baldwin [3] provides a comprehensive survey of protection. More specific studies include Hufbauer et al [21] for the USA, and Anderson and Garnaut [1] for Australia. These surveys suggest that metals, chemicals and minerals are amongst the more heavily protected sectors. A direct comparison in terms of the Effective Rate of Protection (ERP) is informative. Using estimates of protection from the GTAP4

Data Base ([24]), the more pollution intensive industries, chemicals, minerals and metals (Mani and Wheeler ([25]), have an average ERP of 0.05 in the USA and 0.15 in the EU. In contrast, the three least pollution intensive manufacturing industries: transport equipment, electric equipment and machinery equipment (Mani and Wheeler [25]) have an average ERP in the USA of 0.03 and in the EU of 0.11.

[xx] This is one of the central assumptions of the Grossman-Helpman model. It defines the short run political equilibrium, taking longer term considerations as given.

[xxi] In the Grossman-Helpman model, this would provide indirect evidence of the size of α, the weight given to social welfare in the government's objective function.

[xxii] I am grateful to a referee for identifying this interesting issue.

[xxiii] Equilibrium superscripts are ignored where not necessary for notational convenience.

[xxiv] To see this totally differentiate the first-order condition in (5b) to get: $\frac{\partial^2 C}{\partial a^2} da + \frac{\partial^2 C}{\partial a \partial \tau} d\tau = 0$; where: $\frac{\partial^2 C}{\partial a^2} > 0$ (by (A6)) , $\frac{\partial^2 C}{\partial a \partial \tau} = \theta Q(a \frac{\partial^2 v}{\partial a \partial \tau} + \frac{\partial v}{\partial \tau}) < 0$ (since $\frac{\partial^2 v}{\partial a \partial \tau} < 0, \frac{\partial v}{\partial \tau} < 0$). Thus: $\frac{da}{d\tau} = -\frac{\partial^2 C / (\partial a \partial \tau)}{\partial^2 C / \partial a^2} > 0$.