On the choice of instruments for environmental regulation*

Toke S. Aidt, University of Cambridge†

Jayasri Dutta, University of Birmingham‡

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Comments are most welcome

"There is yet no satisfactory theory about the emergence of incentive-based mechanisms." (Hahn, 1990, p.22).

"The past five years have witnessed a dramatic increase in the attention given by policy makers to market-based environmental policy instruments as supplements to the conventional command-and-control standards that dominated the previous to decades of environmental law and regulation." (Stavins, 1995, p. 133).

1 Introduction

This paper proposes a positive theory of environmental regulation; we imagine a democratic society which seeks to lower the level of emissions from industrial production. A fixed target can be implemented by one of many methods. We consider three types of instruments; these are **[Q]**: uniform *quantity controls*; **[P]:** *permits* to pollute that can be traded ; and **[T]**: *taxes* per unit of emission of pollutants. These methods differ in efficiency, and also in the distribution of losses arising from regulation. We attempt to explain the actual patterns observed in different countries, as an evolving policy compromise between disparate interests, represented by industry lobbies and the electorate.

In the last 15 years,the conduct of environmental policy has changed quite significantly. This is reflected in increasingly ambitious environmental targets, and also in the tools used to achieve these targets. Traditionally, environmental regulation has been based on so-called command-and-control instruments, such

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†E-mail: toke.aidt@econ.cam.ac.uk.

‡E-mail: J.Dutta@bham.ac.uk.

as design standards, which require the use of a particular technology, or performance standards or quotas, which prescribe the maximum amount of emission allowable from each source. Although these tools are still widely used in many countries (e.g. Hahn, 1989), a remarkable shift towards the use of incentive-based instruments took place over the 1980's and especially 90's. Economists have long advocated the use of pollution taxes and systems of tradeable permits because of the efficiency advantages that these instruments have compared to quantity controls. Among these, that permits or taxes can achieve a given environmental target at minimum aggregate abatement cost (Baumol and Oates, 1988, chapter 11-12) as well as providing continued incentives for adoption of more efficient abatement technologies (Milliman and Prince, 1989).

Policy choices involve much more than economic efficiency. The emergence of incentive-based instruments in environmental regulation is all the more striking when we take account of political realities of pressure groups and bureaucracies. There are good reasons why quantity regulation may emerge as the politically acceptable alternative. Industry-interests, especially entrenched monopolies, are likely to be in favor because of the short-run profits and entry protection generated (see e.g. Buchanan & Tullock (1975), Boyer & Laffont (1999)); legislators and bureaucrats favor such regulation because of the expert input required and because of familiarity with this type of regulation from other areas (Keohane et. al. (1997)). This theory predicts that societies are likely to give in to pressure groups and use **[Q]**. In reality, it appears, that they have moved to **[P]** or to **[T]**: incentive-based instruments.

To understand why the status of incentive-based instruments has risen in the political arena, it is, therefore, necessary to explain what causes the *political equilibrium* to change from **[Q]** to **[P]** or **[T]**. The purpose of this paper is to explore factors which we believe have contributed to the transition from one political equilibrium to another. We isolate two factors likely to be of importance in this explanation. First, pollution targets have become more ambitious providing incentives to search for more efficient ways of doing things (Hahn, 1989). Second, technological progress, reducing abatement and transaction costs, has reduced the cost of meeting these targets. These developments predict a change in the form of regulation but to understand the underlying mechanisms, a positive theory of policy making is needed. We apply a theoretical model of "policy compromise" developed in earlier work (Aidt & Dutta (2001)). According to this theory, elected politicians are subject to influence by pressure groups, but need to perform satisfactorily to please their electorate. Equilibrium paths display a compromise between disparate interests of special interest groups and the general public.

We analyze a model of environmental regulation in a dynamic democracy. We consider a situation where the pollution target is exogenous given: for example, the country has made a binding agreement to an international protocol. It is possible to extend our analysis to consider the simultaneous choice of target and instrument, an extension not attempted here. Firms produce a consumption good, which pollutes the environment They are heterogeneous in the cost of abatement. Policy decisions are made by democratically elected governments.

To achieve a predetermined pollution target, the government can choose one of three instruments, **[Q]**, **[P]**, and **[T]**. To mirror the type of policy instruments used in Europe and in the US, we deviate from the text book specification of the two incentive-based instruments in several dimensions: we assume that permits are "grandfathered", or allocated to firms according to a pre-specified rule; and that tax revenues are recycled to the public as tax cuts or as provision of public services.[1] In addition, we recognize that permit trading is associated with transaction costs which can reduce significantly the desirability of employing this instrument (Stavins, 1995). Environmental quality is the same under all three instruments.

The political economy of instrument choice is complex and we model a few key aspects. In particular, we focus on the conflict of interest between voters (the general public) and the polluting firms (organized in a lobby group) that arises from the *financial* implications of environmental regulation.[2] We assume that this conflict of interest is mediated by a political process where voters reward politicians by reelection; they do this when **[T]** is the instrument chosen, because this recycles revenues. The industry lobby, representing the polluting firms, can bribe the politician to implement either **[Q]** or **[P]**. We characterize political equilibrium in terms of economic variables: abatement costs, the cost of transactions, and the environmental target. We show, first, that the preferred instrument of the industry lobby varies according to the environmental target. They prefer **[P]** to **[Q]** if the target is stringent; with a very stringent target, they may actually prefer **[T]**. All three instruments can be implemented in political equilibrium and so, be politically acceptable. We use the model to investigate how political acceptability, as a function of these fundamentals, changes over time and demonstrate how falling costs, of abatement and of transactions, can explain the move to **[T]** even with less stringent targets.

The rest of the paper is organized as follows. In section 2, we briefly review recent trends in environmental policy, substantiating the claim that a move towards the use of incentive-based instruments has occurred. In section 3, we survey previous theoretical contributions to the debate about the political econ-

[1]We abstract from the incentive effects associated with the revenue use. By doing so, we neglect, first of all, the important fact that environmental taxes can be used to reduce distortionary taxes on labor and capital and thereby produce a "double dividend" (see Goulder, 1995). As shown by Goulder et al. (1996) this may underestimate the efficiency gains by as much as 25%. We ignore the fact that taxes reimbursed to polluting firms may weaken the incentives to undertake abatement. These simplifications are justifiable insofar as they allow us to focus on the role of the revenue in the generating political compromises.

[2]We, hence, ignore two important groups: environmental lobby groups and the bureaucracy. Environmental lobby groups do play an important role in environmental policy making. Tranditionally, they have been opposed to the use of incentive-based instruments, but this attitude is now changing (Stavins, 1998). For example, the Environmental Defense Fund (EDF), which is one of the more vocal and influence environmental groups in the U.S., supported the U.S. Acid Rain Trading Program. In an interview-based survey of interest groups in Holland, Dijkstra (1999, chapter 5) found that representatives of various environmental organization were more supportive of incentive-based instruments relative to shareholders. Total emission is constant in our model, and environmental lobby groups are likely to be indifferent to instrument choices. The bureaucracy implements policies, and the omission of this pressure group is more substantive.

omy of instrument choice. In section 4, we discuss the formal model; the nature and impact of regulation is set out in 5; section 6 sets out the formalization of political decision making; we characterize political equilibrium in section 7, and analyze the dynamics of transition from one equilibrium to another.

2 Emerging incentive-based approaches to environmental regulation

In this section, we briefly review recent trends in the use of alternative instruments in environmental regulation in Europe and the U.S. A clear picture emerges. Industrial economies have increasingly moved away from [**Q**]; Europe towards [**T**], and the US towards [**P**]. At the international level there has also been an increasing interest in the use of incentive-based instruments. For example, one of the flexibility mechanisms set out by the Kyoto protocol envisions an international market for tradeable CO_2 emission allowances.

- **Environmental taxation in Europe.** The use of environmental taxes of various types has increased during the last 10-15 years in many European countries and the trend is accelerating in some countries (e.g., Sweden, Denmark and the Netherlands) who have implemented far-reaching green tax reforms during the 1990s (OECD, 1997). Other countries like the UK and France are currently implementing environmental taxes to help achieve the targets for greenhouse gas emissions, while Germany and Italy have recently introduced such CO_2 taxes. Measured against GDP, the revenue from all environmental taxes[3] increased from 2.1% to 2.9% between 1980 and 1997 in EU15 (European Environmental Agency, 2000; see Table 1 for a breakdown). The share in total tax revenue has grown by about 14% . Table 1 makes a distinction between three types of environmental taxes: energy taxes, transport taxes and pollution taxes. While energy and transport taxes have an environmental rationale and in many cases are differentiated according to pollution content (e.g., SO_2 or CO_2 content), pollution taxes are levied directly on emissions. We notice that energy taxes are, by far, are the most important environmental taxes.

  Other important aspects of environmental taxation include the way the revenues are used and the extent to which polluters are subject to the same tax liabilities. These two factors are crucial in determining the overall efficiency of environmental taxation. Following Cansier and Krumm (1997), we categorize pollution taxes into two categories: Pure-Tax-Approach (PTA) and Tax-cum-Earmarking (TCE). PTA refers to a situation in which the incentive effect of the tax is in focus and the tax revenue goes into the public budget without being tied to any specific purpose. This opens the possibility for recycling as reductions in distortionary taxes and

[3] Environmental taxes are defined as "taxes with an environmental goal" and include as a major component energy and other product taxes.

Table 1: Environmental Taxes in EU15

Year	Energy tax	Transport tax	Pollution tax
1980	5.84	n.a	n.a
1990	4.71	1.29	0.16
1997	5.18	1.26	0.25

As % of total revenue; from European Environmental Agency 2000

has the potential of generating a “double dividend” (see Goulder, 1995). TCE refers to a situation in which the tax revenue is being earmarked for specific purposes and so, only to a limited extent adds to the general public budget. The motivation for earmarking differs quite a lot and so does the (positive or negative) incentive effects thereof. A widely used principle is to reimburse energy-intensive sectors or firms and to grant certain industries and sectors tax exemptions (see Ekins and Speck, 1999). Tables 2*a* and 2*b* summarize key characteristics of 11 air pollution tax schemes in Europe and Japan. We notice that PTA is used in Sweden, Norway, the Netherlands and Finland, while TCE is prevalent in Denmark, France, Austria and Japan. All countries have introduce some exemptions for CO_2 taxes. In conclusion, environmental taxes have been imposed in many European countries during the 1990s and are actively being considered in many others. While the lion's share of the taxes are (differentiated) energy taxes, pure pollution taxes has also become more popular. In some countries, far-reaching green tax reforms has been introduced, while in others environmental taxes has been accompanied by earmarking and preferential treatment of certain sectors.

Tables 2*a* and 2*b* to appear here.

- **Pollution permit markets in the US.** Since the mid-70s, a number of tradeable-permit systems has been employed in the U.S. to control air and water pollution. Eight of these are summarized in Table 3, adapted from Svendsen (1998, Table 4.1). Five of the programs have been concerned with air pollution, either at the state level or at the national level, the remaining three are concerned with water pollution. Some of these programs were relatively successful (e.g., the lead trading program), while others, such as the Emission Trading program and the Fix River waste water program, were not (see Hahn, 1989). For example, in the Emission Trading Program, many (potential) participants chose the non-trading option or focussed on internal trades; thereby reducing the scope for cost savings. This suggests that the transaction costs implied by the design of these programs were too high to make a viable market possible. The use of permit trading in air pollution regulation has, nevertheless, accelerated during the 1990s, culminating with the Acid Rain Program implemented under Article IV of the Clean Air Act amendment of 1990. The amendment established a national SO_2 allowance program with the aim of reducing U.S.-wide emissions of SO_2 by 50% below 1980 levels by year 2000. The program was introduced in two phases. Phase 1 started in 1995 (and ran until 1999) and covered initially 263 of the dirtiest fossil-fueled electricity generating units operated by 61 electric utilities. Phase 2 started in 2000 and extended the coverage to almost all fossil-fuel electric power plans. The number of permits are allocated to the owners of the affected power plans on yearly basis according to specific rules, primary depending on past emission levels and fuel use. The permits can be banked for future use and can be traded freely throughout the U.S. in both private markets and in a small annual (EPA) auction. The performance of the program has been analyzed in detail by Ellerman et al. (2000).[4] It is concluded that it has been successfully: targets has been more than met; trading volumes have been increasing over time; and the estimated cost saving amounts to about $1 billion a year, compared to the cost of quantity regulation (Stevins, 1998, p. 71). One is tempted to conclude that part of the success of the Acid Rain Program can be attributed to the experience with permit trading gain through the previous programs. This supports the idea that learning-by-doing is of importance.

Permit trading is now being adopted in some European countries to help control CO_2 emission. In the UK, a permit market is to be initiated in April 2001, while in Denmark a market for CO_2 emission permits among electric utilities is to be set up (Ekins and Speck, 2000).

Table 3 to appear here.

3 Theories of Instrument Choice

There is a small but growing literature on the political economy of instrument choices in environmental policy. The classical paper in the area is Buchanan and Tullock (1975). They show how a polluting, competitive industry may prefer quantity restrictions to pollution taxes.[5] The logic is appealing: the quota system enforces a reduction in total industry output, and raises profits. Taxes reduce industry profits, and these financial losses that do not disappear until a sufficient number of firms has reallocated to other sectors. They further argue that "*Those who anticipate benefits from the utilization of the tax revenues, whether from the provision of publicly supplied goods or from the reduction in*

[4] See also Schmalensee et al. (1998) and the review by Cramton (2000).

[5] Maloney and McCormick (1982) analyze further the conditions under which a quota system can be profit-enhancing. Dewees (1982) adds an important aspect to the analysis by pointing out that workers might standards that are tougher for new firms that for old over other types of regulation. Hence, workers and capitalists in a particular industry might have a common interest in support control-and-command regulation.

other tax levies, should prefer the tax alternative and they should make this preference known in the political process" [p. 142]. This point is key to our analysis: instruments are chosen in political equilibrium, that achieves a compromise between the disparate interests of an industry lobby and the general public, who constitute a majority of the electorate. Buchanan & Tullock's argument compares **[Q]** to **[T]**. Including **[P]** in the menu of options introduces an important element.[6] We show that the industry lobby will typically argue for **[P]**, preferring this to **[Q]** when the environment target is sufficiently demanding. **[P]** and **[T]** are both efficient in the allocation of costs. The electorate prefers **[T]**, and can enforce a move to this instrument if there is enough growth, ensuring a fall in total costs of abatement. Buchanan & Tullock's argument suggests that the group of beneficiaries will be politically weak relative to the small, well-organized group of firms and therefore lose out. In contrast, we identify the circumstances under which they may prevail and use this to explain the emergence of the use of incentive-based instruments.

Dijkstra (1999, chapters 8 and 9) analyses the choice between control-and-command instruments and incentive-based instruments in a rent-seeking contest. In a rent-seeking contest, supporters and opponents of different policy instruments can invest effort to increase the probability of getting their favored policy implemented. It is found that incentive-based instruments are chosen with low probability in equilibrium when they are supported by a relatively large group of supporters each with a relatively low per capita stake. This formalizes the argument the Olson (1965) hypothesis, that smaller groups are more likely to have political voice, and is, indeed, the key hypothesis of Buchanan and Tullock. This sort of argument can explain the prevalence of **[P]** rather than **[T]**; both are incentive-efficient, but distribute the gains and losses differently.

Damania (1999) analyses the choice between a pollution tax and an emission standard in a model of political lobbying.[7] Two political parties propose environmental policy platforms to attract campaign contributions from an environmental and an industrial lobby group. It is shown that electoral competition, typically leads to the adoption of a common platform of emission standards, or **[Q]** ; there is, in addition, an equilibrium which the environmental party proposes **[T]**. The logic is that taxes are supported only by the environmental lobby, while quantity restrictions may be supported by both. The industrial lobby has no incentive to propose **[T]**. Once again, this outcome is unlikely to be robust to the introduction of **[P]** in the menu of alternatives. This is an alternative that achieves cost-efficiency, that both groups favor.

These theories are designed to explain why we observe a particular sort of inefficient policy. This **[Q]**, or command and control regulation. They do not explain why we may observe a shift away from this to more efficient policy instruments. This question is addressed formally Boyer and Laffont (1999). They formulate the problem as one of incomplete contracting with asymmetric information, and ask when a society would benefit from constitutional constraints

[6] See also Dewees (1982) for a comparison between tax instruments, control-and-command instruments and tradable permits.

[7] The model is based on Hilman and Ursprung (1988).

on the set of policy instruments. To be specific, they consider a monopolist who has private information about the cost of a project; the project pollutes if undertaken. The regulator has to leave some information rent to the firm. Politicians' scope for diverting part of this rent to their constituencies varies with the regulatory instrument. Two instruments are considered: a single level of allowable pollution ($[\mathbf{Q}]$) and a menu of pollution/transfer pairs ($[\mathbf{T}]$). The first instrument is inefficient but reduces the scope for rent diversion; the second is efficient but allows diversion of rents to the politician. The monopolist (or stakeholders in his rents) resist $[\mathbf{T}]$ for distributional reasons. They show that $[\mathbf{T}]$ provides higher welfare *ex-ante* when the cost of public funds is high and variable, and when the monopoly is unlikely to be efficient. Accordingly, a move towards incentive-based instruments can be explained by movements in these variables.

We take the set of instruments as given, as $\{[\mathbf{Q}], [\mathbf{P}], [\mathbf{T}]\}$, and do not consider the possibility of constitutional constraints, and evaluate when and whether they are politically acceptable: specifically, when is any one of these part of a *political equilibrium.* We offer a dynamic model which is well-suited to study the evolution of political equilibrium over time and so to explain the change of policy instruments over time. Tax-payers vote, and this explicitly accounted for in our analysis.

4 The Economy

Economic activity, and policy choices, take place over infinite discrete time, $t = 0, 1, 2, \cdots$. Consumers live for ever, and have utility defined over the consumption of a numeraire good y, a produced good x, and a public good g as well as environmental quality, $1 - e$, with e the level of emissions of pollutants. The representative citizen-consumer has utility

$$\sum_{t=0}^{\infty} \beta^t [y_t + g_t + u(x_t) + u(1 - e_t)].$$

They are endowed with $\bar{y}$ every period, and buy x_t in response to its price p_t every period. The public good is financed by pollution taxes, where applicable: we can think of this as direct redistribution of tax revenues.

A continuum of firms, of measure 1, produce good x. Each firm produces one unit at zero marginal cost. Total production is $x_t = 1$, implying $p_t = p = u'(1)$. Production of x pollutes the environment; in the absence of regulation, each firm emits one unit, so that $e_t = 1$. Firms can lower emissions at a cost; the cost of abatement differs across firms and over time. Let $a_i = 1 - e_i$ be the abatement level of firm i. The cost function is

$$C_{it}(a_i) = \frac{a_i^2}{2\theta_{it}} = \frac{(1 - e_i)^2}{2\theta_{it}}.$$

We assume, in addition, that

$$\theta_{it} = A_t \theta_i.$$

Firms differ in abatement costs, and this is captured by the fact that θ_i differs across firms. A firm with low θ_i has higher costs of abatement. Technical progress increases A_t, resulting in a proportional reduction of all costs: we assume $A_{t+1} \geq A_t$. The distribution of cost differentials is stationary over time, and represented by the distribution $F(\theta)$ on the interval $[\theta_L, \theta_H]$. Two characteristics of F are important in our analysis: the expectation, or arithmetic mean

$$\mu = \int_{\theta_L}^{\theta_H} \theta dF(\theta) = E\theta;$$

and the harmonic mean

$$\eta = \frac{1}{\int \frac{1}{\theta} dF(\theta)} = \frac{1}{E\frac{1}{\theta}}.$$

We assume that both are finite and positive. By Jensen's inequality, $\eta < \mu$ whenever the distribution F is non-degenerate.

We consider a society that has decided to reduce emission according to a predetermined target, denoted $\bar{e}_t \in (0, 1]$, and $\bar{e}_{t+1} \leq \bar{e}_t$. We can think of this as a commitment made in international negotiations such as the Kyoto Protocol, according to which the signatories has committed themselves to reduce emission to by about 8% relative to 1990 levels of emissions by 2008-2012. The UK government has in addition to this its own domestic goal of reducing emissions of CO_2 by 20% relative to 1990 levels by 2010. Reductions of this magnitude require a major regulatory effort. We assume that the society can achieve the target using one of three policy instruments as indicated next.

5 Environmental Regulation

The target $\bar{e}_t$ can be achieved by means of one of three policy instruments, **[Q]**, **[P]**, **[T]**. Here, we describe the operation of each instrument and its effects on the private sector. The actual policy choice is endogenous and to be determined in each period in political equilibrium. Not surprisingly, distributional effects plays a key role in determining equilibrium outcomes. We assume that governments cannot observe θ_i for each firm, but know A_t as well as the distribution $F(\theta)$.

5.1 Quantity Controls: [Q]

We consider a highly stylized version of a system of quantity controls. The government has to implement an aggregate emissions target $\bar{e}_t$, and cannot observe the type, θ_i and tailor emission targets appropriately. A uniform emission quota system is used.[8] The quota is only valid one period and requires each

[8] In really more complex control-and-command instruments have been used, including specific requirements regarding technology choice, differential treatement of new and old firms and so on.

firm to reduce emission down to $\bar{e}_t$. Doing so, in turn, requires abatement effort of $\overline{a}_t = 1 - \bar{e}_t$ per firm and per period profits are

$$V_{it}(\mathbf{Q}) = p - \frac{(1-\bar{e}_t)^2}{2\theta_{it}}; \tag{1}$$

Total industry profits are

$$\bar{V}_t(\mathbf{Q}) = p - \frac{(1-\bar{e}_t)^2}{2A_t\eta}. \tag{2}$$

We note that profits are positive for every firm whenever $\bar{e}_t > 1 - \sqrt{2p\theta_L A_0}$ and we assume that this holds at each t.[9] The instrument $[\mathbf{Q}]$ does not achieve abatement at lowest cost; the marginal cost of abatement is higher for low-θ firms. This is clear from the analysis of alternatives.

5.2 Traded Permits [P]

Suppose that each firm is issued a permit to pollute $\bar{e}_t$ units. Firms are allowed to trade permits between themselves. Organizing and maintaining an effective market is costly for numerous reasons: search and information collection is costly; bargaining and decisions costs can be high as can monitoring and enforcement costs (Stavins, 1995). We capture this important aspect of permit trading by assuming that there is a fixed cost $\phi_t = \frac{\phi_0}{A_t}$ of trading permits shared by all participating firms.[10] Note that technological progress is assumed to reduce transactions costs, at the same rate as abatement costs.

Suppose permits are traded at price q_t. Firm i chooses its pollution level to maximize its profit

$$V_i(e_i, q_t) = p + q_t(\bar{e}_t - e_i) - \frac{(1-e_i)^2}{2\theta_{it}} - \phi_t.$$

Profits are maximized at

$$(1 - e_i) = q_t\theta_{it}.$$

Market clearing implies

$$1 - \bar{e}_t = q_t E\theta_{it} = q_t A_t \mu;$$

[9] Note that this is true for all $\bar{e} > \mathbf{0}$ if $U'(1) \geq \frac{1}{2A_0\theta_L}$. This condition suffices to ensure non-negative profits in each regime. Note that we are ruling out the possibility that some firms may exit, or others enter when regulation is imposed, in contrast to Buchanan & Tullock (1975). Free entry outcomes change the actual solutions at economic equilibrium following policy choices; the relative valuation of instruments remain valid in that context.

[10] This is slightly different from a situation where firms choose whether or not to pay a cost and trade. Modelling the transaction cost as a fixed cost also implies that there is no marginal distortions and a permit market, if viable, will therefore produce the least cost allocation. Stavins (1995) has shown that this is not the case if transaction costs are related to the volume of trade in a nonlinear way. We maintain the current assumption for simplicity, but note that permit trading becomes less attractive for the industry as a whole of the deviation from the least cost allocation is substantial.

or

$$q_t = \frac{1 - \bar{e}_t}{A_t \mu}.$$

Substituting in the expression for profits yields

$$V_{it}(\mathbf{P}) = p + \frac{(1 - \bar{e}_t)^2}{2A_t \mu^2}(\theta_i - 2\mu) - \frac{\phi_0}{A_t} \tag{3}$$

and total industry profits

$$\bar{V}_t(\mathbf{P}) = p - \frac{(1 - \bar{e}_t)^2 + 2\mu\phi_0}{2A_t \mu}. \tag{4}$$

Comparing expressions (2) and (4), we obtain the following result.

Lemma 1 *Let $\bar{e}_t < 1$, and $\Delta \equiv \frac{1}{\eta} - \frac{1}{\mu} > 0$. Industry profits are higher under [**P**] than under [**Q**] if, and only if*

$$\begin{array}{rcl} \bar{V}_t(\mathbf{P}) & \geq & \bar{V}_t(\mathbf{Q}) \Leftrightarrow \\ (1 - \bar{e}_t)^2 & \geq & 2\frac{\phi_0}{\Delta} \Leftrightarrow \\ \bar{e}_t & \leq & \varepsilon_1 \equiv 1 - \sqrt{\frac{2\phi_0}{\Delta}} \end{array}$$

We note that $V_{it}(\mathbf{P}) > V_{it}(\mathbf{Q})$ whenever $\phi_0 = 0$. Each firm makes higher profits in the traded permits system in the absence of transactions costs. These are pure gains of allocative efficiency, measured as $(1 - \bar{e})^2 \frac{\Delta}{2}$ in the aggregate. Lemma 1 states the condition that efficiency gains must outweigh transactions costs. We note, in addition, that total profits are higher in the inefficient policy regime, [**Q**], if $\bar{e}_t$ is sufficiently large. In the initial phase of a program of gradual abatement, firms will favor for this method of regulation.

5.3 Pollution Taxes (T)

As an alternative to the permit system, the government can levy a tax on emissions, at rate τ_t. Firm i pays $\tau_t e_i$ if it chooses pollution level e_i. It will choose e_i to maximize its profit

$$V_i(e_i, \tau_t) = p - \frac{(1 - e_i)^2}{2\theta_{it}} - \tau_t e_i;$$

yielding the first order condition

$$1 - e_i = \tau_t \theta_{it}.$$

To hit a target of $\bar{e}_t$, the tax rate must be[11]

$$\tau_t = \frac{1-\bar{e}_t}{A_t\mu}.$$

Substitutions yield expressions for firms' profits

$$V_{it}(\mathbf{T}) = V_{it}(\mathbf{P}) + \frac{\phi_0\mu - \bar{e}_t(1-\bar{e}_t)}{A_t\mu} \tag{5}$$

and industry profits

$$\bar{V}_t(\mathbf{T}) = \bar{V}_t(\mathbf{P}) + \frac{\phi_0\mu - \bar{e}_t(1-\bar{e}_t)}{A_t\mu}. \tag{6}$$

We note that the two systems, **[P]**, and **[T]**, achieve exactly the same allocation of emissions and costs. Firms that choose e_i larger than average pay the same price in the two systems, but under the tax scheme, they pay this as taxes to the government rather than as permit revenues to low-cost firms. They save on the transaction cost ϕ_t, but lose the revenue $q_t\bar{e}_t$. Equations (5), (6) demonstrate these effects clearly.[12] We obtain the next result by direct evaluation of (6).

Lemma 2 *Let $\bar{e}_t < 1$ and $\phi_0\mu \le \frac{1}{4}$. Define $\varepsilon_2 \equiv \frac{1}{2} - \sqrt{\frac{1}{4} - \phi_0\mu}$. Industry profits are higher under **[P]** than under **[T]** if, and only if*

$$\bar{e}_t(1-\bar{e}_t) > \mu\phi_0 \Leftrightarrow$$

$$\varepsilon_2 < \bar{e}_t < 1 - \varepsilon_2.$$

Lemma 2 establishes that **[P]** is preferred to **[T]** unless $\bar{e}$ is either close to 0 or to 1. The financial difference between the two systems is the total tax bill, $\bar{e}(1-\bar{e})/\mu A_t$. This amount is too small to compensate for transactions costs ϕ_t if environmental standards are extremely lax, or extremely stringent. In the first case, the tax rate is small; in the second, the tax base is small.

5.4 Profits and Instruments

From the comparison of industry profits in the three systems, we note that the two least cost systems need not correspond to highest profits. Proposition 3 completes the argument and establish that each system achieves the highest profit for some emission target $\bar{e}_t$. This has important consequences for the preferences of the special-interest group representing the industry that we elaborate on below. Table 4 summarizes industry profits in each policy regime.

[11] To set the tax rate at the right level, the politician needs to have information about average abatement costs.

[12] We consider a simpler tax policy than Boyer & Laffont (1999), where firms face a schedule $T(e_i)$. This simplification is costless because $\bar{e}_t$ is exogenous. We return to the issue of tax reimburesement in the discussion below.

Table 2: Table 4: Policy Instruments and Industry Profits

Policy [S]	Profits $\bar{V}(\bar{e}, A)$
[Q]	$p - \frac{(1-\bar{e})^2}{2\eta A}$
[P]	$p - \frac{(1-\bar{e})^2}{2\mu A} - \frac{\phi_0}{A}$
[T]	$p - \frac{(1-\bar{e})^2}{2\mu A} - \frac{\bar{e}(1-\bar{e})}{\mu A}$
$\mu = E\theta$	$\frac{1}{\eta} = E\frac{1}{\theta}$

Proposition 3 *Assume* $0 < \phi_0 < \frac{2\eta}{\mu}\frac{\mu-\eta}{(\mu+\eta)^2}$. *There exists a* ε_H *and a* ε_L *such that* $0 < \varepsilon_L < \varepsilon_H < 1$ *and*

1. $\bar{V}_t(\mathbf{T}) \geq \max[\bar{V}_t(\mathbf{P}), \bar{V}_t(\mathbf{Q})]$ *whenever* $0 \leq \bar{e}_t < \varepsilon_L$;
2. $\bar{V}_t(\mathbf{P}) \geq \max[\bar{V}_t(\mathbf{Q}), \bar{V}_t(\mathbf{T})]$ *whenever* $\varepsilon_L \leq \bar{e}_t < \varepsilon_H$;
3. $\bar{V}_t(\mathbf{Q}) \geq \max[\bar{V}_t(\mathbf{P}), \bar{V}_t(\mathbf{T})]$ *whenever* $\varepsilon_H \leq \bar{e}_t < 1$.

Proof. We note, from Lemma 1, that $\bar{V}_t(P) \geq \bar{V}_t(Q)$ whenever $\bar{e}_t \leq \varepsilon_1$; from Lemma 2, that $\bar{V}_t(T) > \bar{V}_t(P)$ if $\bar{e}_t < \varepsilon_2$. Comparing equations (2), (6) and (4), we obtain

$$\bar{V}_t(Q) \geq \bar{V}_t(T) \Leftrightarrow \bar{e}_t \geq \varepsilon_3 \equiv \frac{\mu-\eta}{\mu+\eta}.$$

The condition $\phi_0 < \frac{2\eta}{\mu}\frac{\mu-\eta}{(\mu+\eta)^2}$ implies $\varepsilon_2 < \varepsilon_3 < \varepsilon_1$, so that $\bar{V}_t(\mathbf{Q}) \geq \bar{V}_t(\mathbf{P}) \Rightarrow \bar{V}_t(\mathbf{Q}) > \bar{V}_t(\mathbf{T})$. It suffices to set $\varepsilon_L = \varepsilon_2$ and $\varepsilon_H = \epsilon_1$ ■

The effect of instrument choices on industry profits can be understood quite intuitively and is illustrated in Figure 1.

We note, first, that in the absence of transactions costs, $\bar{V}(\mathbf{P})$ always exceeds $\bar{V}(\mathbf{Q})$ and $\bar{V}(\mathbf{T})$: $\varepsilon_L = 0$ and $\varepsilon_H = 1$ whenever $\phi_t = 0$. Small costs of trading in permits can change this. Suppose, first, that the environmental target is lax, i.e., $\bar{e} \simeq 1$. The benefits of trading permits are positive, but small relative to ϕ. Similarly, the relative benefit of permits trading is large if firms are very heterogeneous. In our model, the difference $\Delta = \frac{1}{\eta} - \frac{1}{\mu}$ increases with the degree of heterogeneity, and so raises $\bar{V}(\mathbf{P}) - \bar{V}(\mathbf{Q})$. If cost differences are negligible, the likely gains of allocative efficiency are also small.[13] The fact that $\bar{V}(\mathbf{T}) > \bar{V}(\mathbf{P})$ is somewhat counterintuitive, because taxes are net transfers from industry to consumers. This arises because of the cost of transactions, as well as the "Laffer curve" of pollution taxes. The total pollution tax bill is proportional to $\bar{e}(1-\bar{e})$. When environmental regulation is particularly strict, $\bar{e}$ is near zero, and firms

[13] See also Boyer and Laffont (op.cit.). Dispersion increases $V(T) - V(Q)$, but must increase $V(P) - V(Q)$ at the same time.

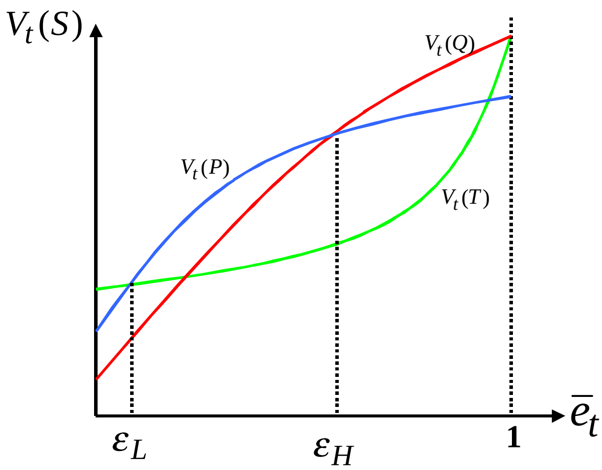

Figure 1: The stringency of environmental regulation and industry profits under the three regulatory regimes.

pay very little in taxes. Their tax-bill is small enough relative to the fixed cost of trading permits, and also small relative to the cost of allocative inefficiency of quantity regulation.

Proposition 3 identifies the preferences of the industry lobby. To see how these might change over time, consider the following thought experiment. The initial level of pollution is uncontrolled ($\bar{e}_0 = 1$); the government has signed a binding international agreement to lower emissions to zero over T periods ($\bar{e}_T = 0$). The industry lobby, composed of owners of all firms, seeks to influence policy choices every period. They are able to pool their resources and make transfers among each other, and are therefore interested in the policy instrument that maximizes aggregate profits. As the emissions target $\bar{e}_t$ falls from 1 to 0, it must transit from above ε_H to below ε_L. In the initial phase, $\bar{e}_t > \varepsilon_H$. Total industry profits are highest if the policy regime is [**Q**], and this is the policy instrument they are likely to lobby for, much as Buchanan and Tullock (1975) deduce. Notice however that the logic is different. In our model, industry lobby prefers [**Q**] because the efficiency gain (from least cost abatement) is not sufficient to out weight the transaction cost of permit trading. Similarly, there comes a time $\tilde{t}$ such that the environmental target $\bar{e}_{\tilde{t}}$ falls below ε_L, and there is consensus to switch to [**T**], as predicted in Boyer and Laffont (1999). In the intermediate phase, which may last for a long time, the preferred policy of this lobby is [**P**]. An implication, then, is that we should observe societies passing through the [**P**] phase, provided they face similar transactions costs. This is not what we observe: the typical transitions are from [**Q**] to [**P**] (in the US) and from [Q] to [T] in Europe: a positive theory of instrument choice should be capable of understanding this phenomenon; to put it more boldly, any such theory is incomplete in the absence of alternative [P].

6 The Political Market

We imagine that the policy regime that prevails at a given point in time is the outcome of a political process that trades off the interests of politicians, organized lobby groups and voters. A positive theory of policy choices starts from the point of view that it is unrealistic to imagine the governments are universally benevolent, and that any inefficiency will be corrected when it is noticed. Similarly, we feel that it equally unrealistic to imagine that special interest groups can dictate policy always and everywhere, irrespective of the political concerns of elected government, as in the theory of regulatory capture (Stigler, 1971). Our analysis evaluates the senses in which policy outcomes achieve a compromise between the welfare of the general public, who has the power to dismiss elected governments, and of the industry lobby, who is willing to pay to see its preferred policy implemented, and can compensate politicians for loss of office if necessary. We show that this can help to explain a transition to policy [T] in circumstances where the lobby prefers [P] or [Q], in an economy with productivity growth.

We propose a model of dynamic democracy, following on earlier work (Aidt & Dutta, 2001). The model has three key elements:

1. **Repeated elections and performance voting.** Voters delegate decision making power to politicians in democratic elections. Politicians cannot commit to policy actions before an election and once in office they can implement the policy that they want and potentially respond to the lobbying activities of organized interests (see below). Voters observe the policy implementation and hold the politician responsible for the choice in the next election. In particular, as in Barro (1973) and Ferejohn (1986), we assume that voters try to control politicians by setting performance standards. We assume that consumers holds a majority.[14] At the beginning of each period, voters announce an election rule, $\eta(s)$, which specifies whether or not the incumbent politician is being reelected as a function of the policy implemented. Formally, the election rule is a mapping from $\{\mathbf{Q}, \mathbf{P}, \mathbf{T}\} \to \{0, 1\}$ where $\eta_t(S) = 1$ indicates that the incumbent is reelected and $\eta_t(S) = 0$ that he is not and a challenger enters office. From the analysis in section 5, we know that voters prefer [T] to either [Q] or [P].[15] It follows immediately that they will employ the following station-

[14] The owners of the firms can vote but would not be able to further their interest via elections due to their small number.

[15] Voters are indifferent among the three instruments in the degenerate cases $\bar{e}_t = 0$ or $\overline{e}_t = 1$. The model can easily be extented to the situation in which part of the revenue is reimbured to the industry.

ary election rule:

$$\eta(S_t) = \begin{cases} 1 & \text{if} \quad S_t = T \\ 0 & \text{otherwise} \end{cases} \tag{7}$$

2. **Lobbying activities**. It is clear from section 5 that firms have a strong interest in environmental regulation. We assume that all firms in the industry join forces and organize a lobby group, despite the free rider problem (Olson, 1965). The industry lobby group represents the interests of all firms sincerely in the political process and is able to redistribute revenues among the membership.[16]

   We assume that the lobby group offers payments to the politician in return for specific policies, as in Berheim and Whinston (1986) and Dixit, Grossman and Helpman (1996). We think of these payments as benefits that occur to the politician personally and a natural interpretation is that they represent bribes. The important point to stress is that the lobby group has access to a more powerful control instrument than voters. The lobby group can offer explicit incentives while voters can only offer implicit incentives via the threat of terminating the tenure of an "underperforming" politician. Formally, a lobbying strategy is a payment function, $b(S)$, that map policy choice made by the incumbent into a monetary payment. The lobby group discount the future at rate β and has total payoff equal to $\sum_{t=0}^{\infty} (U(s_t) - b(S))$. The per period, gross payoffs, $\bar{V}(S)$, are summarized in Table 4.

3. **Power and Money.** Politicians care about holding office for many reasons. We focus on two, namely money and power. Politicians may like power for its own sake. To capture this we assume that a politician receives the ego-rent, m, each period he or she holds office. We assume that m is the same for all politicians. In addition, holding (decision making) power allows the politician to collect payments from the lobby group. The per-period payoff of an elected politician is

$$m + b(S). \tag{8}$$

   We assume that a politician that is voted out of office is never reelected and will get some reservation level of utility, normalized to zero. Like other agents in the economy, politicians discount the future at the rate β.

The timing of events is a follows. Each period an election takes place. Immediately after each election, voters announce an election rule. This is observed by all. Next, the lobby group announces a payment function to the politician.

[16] We have chosen the formulation with only one industry lobby group for simplicity, and also because separate lobbies would identify θ_i and the efficiency rationale for [**P**] or [**T**] would be irrelevant.

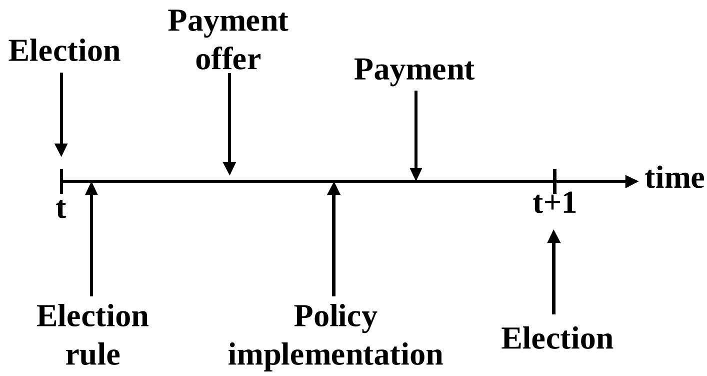

Figure 2: The timing of events.

Taking as given the election rule and the payment function, the policy making implements a policy. The payment is then made and an election is held. This sequence of events repeat itself every period. The sequence of events is summarized in Figure 2.

Following Coate and Morris (1999), we define political equilibrium as a Markov perfect equilibrium of this game. We are going to analyze how the political equilibrium changes when the key parameters, $\bar{e}_t$ and A_t, evolve over time. However, before we do so, we characterize the set of stationary political equilibria.

7 Political Equilibrium

Assume that $\bar{e}_t = \bar{e}$ and $A_t = A$. This makes the economy completely stationary and if something is an equilibrium in period t so it is in period $t+i$, $i = 1, ..., \infty$. We can therefore focus our attention on a particular period. Proposition 4 summarizes the possible equilibrium configurations and shows that each of the three policy instrument can be implemented in political equilibrium.

Proposition 4 *Define* $M = \frac{\beta m}{1-\beta}$. *Then the following stationary policy sequences are implemented in Markov perfect equilibrium:*

1. $\widehat{S} = \mathbf{Q}$ *if* $\bar{e} \geq \varepsilon_H$ *and* $\bar{V}(\mathbf{Q}) \geq \bar{V}(\mathbf{T}) + M$*;*
2. $\widehat{S} = \mathbf{P}$ *if* $\varepsilon_L \leq \bar{e} \leq \varepsilon_H$ *and* $\bar{V}(\mathbf{P}) \geq \bar{V}(\mathbf{T}) + M$*;*

3. $\widehat{S} = \mathbf{T}$ *otherwise.*

Proof. The value function of the incumbent politician is

$$v(S_t) = b(S_t) + m + \eta(S_t)\beta v(S_{t+1}) \tag{9}$$

- The lobby group designs its payment function $b(S_t)$ to maximize

$$\sum_{i=0}^{\infty} \beta^i [U(S_i) - b(S_i)]$$

knowing that the politician implements the policy that maximizes equation (9) and that voters follow the election rule, $\eta(S_t) = 1 \Leftrightarrow s_t = T$. Since the periods are not physically linked, the lobby designs $b(S_t)$ to maximize current net benefit.

- Clearly, the lobby group will never pay to see [**T**] implemented as the politician is happy to do that in the absence of any lobbying and so, $b(\mathbf{T}) = 0$. Further, the lobby group will choose $b(\mathbf{P}) > 0$ only if $\bar{e} \in [\varepsilon_L, \varepsilon_H]$ implying $\bar{V}(\mathbf{P}) = \max V(\mathbf{S})$, and similarly $b(\mathbf{Q}) > 0 \Rightarrow \bar{e} \in [e_H, 1]$, from Proposition 3.

- If the politician were to implement $S_t \neq T$, he would lose the next election. Hence, to get him to do so, the lobby group must compensate for the loss of office, i.e., pay $\beta v(S_{t+1}) = \frac{\beta m}{1-\beta} \equiv M$. The lobby is willing to pay this if, and only if $\bar{V}(S) - b(S) \geq \bar{V}(\mathbf{T})$, and chooses $b(S) = 0$ for each S otherwise. The proposition follows by substitution

■

Proposition 4 shows that equilibrium policy depends crucially on underlying economic fundamentals, notably abatement technology and the emissions target to be implemented. These variables evolve over time and can therefore affect the nature of equilibrium policy and help explain changes in policy regimes. We show, in Proposition 5, how policy choices at time t respond to these changes by means of a stationary policy function $S_t = \mathcal{S}(\bar{e}_t, A_t)$.

Proposition 5 *Let* $\bar{e}_t \leq \bar{e}_{t-1}$ *and* $A_t \geq A_{t-1}$*. At political equilibrium, instrument choices are*

$$\begin{aligned}
S_t &= \mathbf{Q} && \text{if } \bar{e}_t \geq \varepsilon_H \text{ and } A_t \leq \frac{1-\bar{e}_t^2}{2M\mu} - \frac{(1-\bar{e}_t)^2}{2M\eta}; \\
S_t &= \mathbf{P} && \text{if } \varepsilon_L \leq \bar{e}_t \leq \epsilon_H \text{ and } A_t \leq \frac{\bar{e}_t(1-\bar{e}_t) - \mu\phi_0}{M\mu}; \\
S_t &= \mathbf{T} && \text{otherwise.}
\end{aligned}$$

Proof. The proof follows from Proposition 4. Payoffs $\bar{V}_t(S)$ are stationary functions of $\bar{e}$ and A. This follows from Proposition 3. As before, [**P**] is an equilibrium at time t if, and only if

$$\texttt{(EP1)} \quad \bar{V}_t(\mathbf{P}) \geq \bar{V}_t(\mathbf{Q})$$

and

$$\texttt{(EP2)} \quad \bar{V}_t(\mathbf{P}) \geq \bar{V}_t(\mathbf{T}) + M.$$

Similarly, [**Q**] is an equilibrium at t if, and only if

$$\texttt{(EQ1)} \quad \bar{V}_t(\mathbf{Q}) \geq \bar{V}_t(\mathbf{P})$$

and

$$\texttt{(EQ2)} \quad \bar{V}_t(\mathbf{Q}) \geq \bar{V}_t(\mathbf{T}) + M.$$

Proposition 5 obtains by substitution of the relevant expressions for $\bar{V}_t(S)$ in (EP1), (EP2), (EQ1) and (EQ2) and notice that if one of the conditions fails, then [**T**] prevails ■

Propositions 4 and 5 reveal a number of interesting results about transitional politics and environmental instrument choices in a democracy, which we discuss in some detail below.

- **The emissions target:** In Proposition 4, we evaluate stationary policy outcomes, and show that tax policies, [**T**], are implemented whenever $\bar{e}$ is not too high. From Proposition 3, the lobby group prefers [**P**] or [**Q**] depending on the stringency of the emissions target. Voters prefer [**T**], and industry lobbies have to pay relatively high bribes to compensate politicians for potential loss of office. They are willing to do this only if their net gains are high. Proposition 5 shows that the willingness to pay changes along equilibrium paths with increasingly stringent targets. This is illustrated in Figure 3. Consider the situation in which $A_t = A_0 \approx 0$. For relatively lax targets $(\overline{e}_t)$, the industry lobby prefers [**Q**] and is willing to compensated the politician for the loss of office and so [**Q**] is the initial equilibrium. As the target becomes more ambitious and more abatement needs to be undertaking, the lobby group becomes more favorable to idea of permit trading, trading off the efficiency gains against the transaction cost of running the market. When the target falls below ε_H the equilibrium shifts to [**P**]. As the target emission level is further reduced, the lobby group becomes more favorable to [**T**] because the financial burden of paying the tax for unabated pollution falls relative to the (fixed) transaction cost of permit trading and at some point when the target is close to ε_L the equilibrium shifts to [**T**] and the government is reelected each period. It is possible to have a direct transition from [**Q**] to [**T**]. If for example, $\phi_0\mu = \frac{1}{4}$, then a permit equilibrium is ruled out and the economy transit directly from command-and-control into taxes when the target fall below ε_H. This is illustrated in Figure 4. These transitions may help explain the observed patterns in Europe and the US.
- **Productivity growth:** The quantities $\bar{V}(\mathbf{P}) - \bar{V}(\mathbf{T})$ and $\bar{V}(\mathbf{Q}) - \bar{\mathbf{V}}(\mathbf{T})$ decline with A. As productivity increases, profit differences decline, and

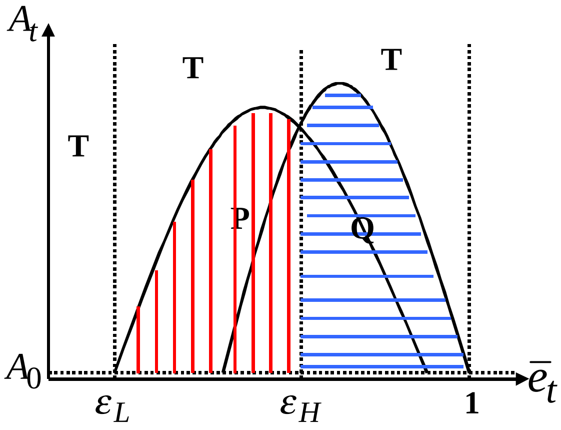

Figure 3: Political equilibrium with low transaction costs.

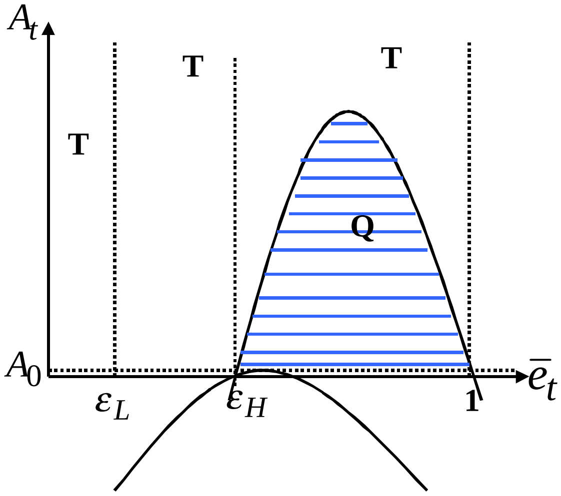

Figure 4: Political Equilibrium with high transaction costs.

so does the willingness to pay of industry lobby groups. Suppose, for example, that $\bar{e}_t = \bar{e}$ and

$$A_{t+1} = A_t(1+g); \quad g > 0.$$

This is a scenario of constant productivity growth that reduces costs over time. From Proposition 5, we see that this indexes a transition from **[P]** to **[T]** if $\bar{e} \in (\varepsilon_L, \varepsilon_H]$ and from **[Q]** to **[T]** if $\bar{e} \in [\varepsilon_H, 1)$. Tax instruments are more likely as costs fall. We notice that productivity growth cannot by itself explain the differences between Europe and the US, but it can help explain why the political acceptability of tax instruments may increase as firms learn to deal with abatement in more effective ways. Importantly, this implies that tax revenues fall, so that the transition occurs when there are relatively few taxes to collect and so, when tax instruments are of less interest from a fiscal point of view.

- **Transactions costs:** The permit system becomes more appealing when ϕ_0 is lower (compare Figures 3 and 4). We assume that ϕ_t falls at the same rate as abatement costs. If there is a lot of learning-by-doing in running and operating a permit market, then decrease in ϕ_t may be accelerated if a market gets going; suggesting that the decline in ϕ_t is only relevant in the **[P]** regime.[17] This would make **[P]** a persistent policy (in the sense of Coate & Morris (1999)). This may help explain the U.S. experience with permit trading. Importantly, Proposition 5 predicts that a transition to **[T]** occurs with rising A_t or with very strict targets *even if* $\phi_0 = 0$. Policy persistence is a temporary phenomenon.

- **Electoral concerns and corruptibility:** An increase in m, or in β, increases re-election concerns of the incumbent government. It is more willing to please its electorate, and to move to **[T]** faster. The lack of term limits in many European countries increase β and can explain that more attention is paid to voter interests. Similarly, societies may differ in the degree to which politicians can receive compensation from special interest groups; limits on campaign contributions, or implementation of anti-corruption legislation, is likely to limit $b(S)$ and so speed up the transition to **[T]**.

- **Heterogeneity:** Higher dispersion in the distribution of productivity increases $\mu - \eta$. This has no impact on the relative payoffs of **[P]** and **[T]**; it does, however, lower the payoff of **[Q]** and implies a faster transition to **[T]**.

- **Revenue uses** In Europe, the move from **[Q]** to **[T]** was often accompanied by recycling the revenue partly to voters and partly to industry: the

[17] Anecdotal evidence from the U.S. supports this hypothesis. The prevalence of internal trading within firms in the initial phases of the U.S. trading schemes (such as the Emission Trading Program) which was replaced by significant external trading in the subsequent Acid Rain Program is one piece of evidence. Another is the emergence of various intermediaries and brokers.

actual policy is intermediate between **[P]** to **[T]**. It is relatively simple to show that the industry lobby will block such an intermediate regime less often; it is more difficult to reconcile with the preferences of voters, but may reflect the limited set of control instruments at their disposal.

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Table 2a: Overview of SO_2 taxes in selected European countries, 2000.

Country	Year of introduction	Revenue use	Revenue yield (1995) in % of total tax revenue	Category	Comments
Sweden	1991	No earmarking	0.05%	Pure-tax approach	Motivated by economic efficiency
Denmark	1996	Tax-burden compensation	n.a.	Tax-cum-earmarking	Motivated by economic efficiency
Norway	1993 (1970)	No earmarking	n.a.	Pure-tax approach	Motivated by economic efficiency
France	1985	Abatement subsidy	n.a.	Tax-cum-earmarking	Motivated by fiscal concerns
Japan	1974	Compensation of victims	n.a.	Tax-cum-earmarking	Motivated by equity concerns
Czech Republic	1999	Earmarking for environmental expenditure	n.a.	Tax-cum-earmarking	
Slovakia	2000	Earmarking for environmental expenditure	n.a.	Tax-cum-earmarking	
Estonia	1999	No earmarking	n.a.	Pure-tax approach	
Poland	1999	Earmarking for environmental expenditure	n.a.	Tax-cum-earmarking	

Source: Cansier and Krumm (1997), Ekins and Speck (1999, 2000) and OECD (1997).

Table 2b: Overview of CO_2 taxes in selected European countries, 2000.

Country	Year of introduction	Revenue use	Revenue yield (1995) in % of total tax revenue	Category	Comments
Sweden	1991	No earmarking but exemptions. Reduction in personal income tax	1.9%	Pure-tax approach	Differentiated tax
Denmark	1992/1995/1998	Tax-burden compensation and reduction in income taxes.	n.a.	Tax-cum-earmarking	Differentiated tax
Norway	1991	No earmarking but exemptions	2%	Pure-tax approach	Non-differentiated
Netherlands	1990/1996	No earmarking (after 1992), but exemptions. Personal income tax reduction.	1.3%-2.6%	Pure-tax approach	
Finland	1990/1997	No earmarking and few exemptions	1.4%	Pure-tax approach	Differentiated
Austria	1996	Earmarking, reimbursement	n.a.	Tax-cum-earmarking	
Germany	1999/2000	Reduction in Social Security	n.a.	Pure-tax approach	Energy tax
Italy	1999	Reduction in Employment Charges	0.2%	Pure-tax approach	

Source: Cansier and Krumm (1997), Ekins and Speck (1999, 2000) and OECD (1997).

Table 3: Selected Emission Trading Programs in the U.S.

Program	Target	Period	Location	Target group
Air				
Emission Trading Program	National Standards	1974-?	US	Industry
Lead Trading	Lead phase-out	1982-87	US	Refineries
CFC/Halon	CFC/Halon phase-out	1989-96	US	Industry
Acid Rain Program	50% reduction in SO_2	1990-?	US	Electric utilities
Regional Clean Air Incentive Market	75% reduction of NO_x, and 60% reduction of SO_x	1994-2003	California	Industry
Water				
Fox River	State standards	1981-?	Wisconsin	Paper/pulp mills
Dillon Reservoir	State standards	1984-?	Colorado	Municipal waste treatment and non-point sources.
Tar-Pamlico River Basin	35% reduction of nutrients	1991-2004	North Carolina	Point/non point sources

Source: Adopted from Svendson (1998, Table 4.1).