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Transitional Politics: Emerging Incentive-based Instruments in Environmental Regulation

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Transitional Politics: Emerging Incentive-based Instruments in Environmental Regulation[*]

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Comments are most welcome

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“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 two decades of environmental law and regulation.” (Stavins, 1995, p. 133).

Abstract

In the past 15 years, incentive-based environmental policy instruments, such as pollution taxes and tradeable pollution permits, have become an important supplement to tradition command-and-control instruments in Europe and the U.S. This paper proposes a positive theory of environmental instrument choice that can be used to explain this trend. We imagine a democratic society that seeks to lower the level of pollution from industrial production to a pre-specified target. The target can be implemented by one of three instruments: **[Q]**: *quantity controls*; **[P]:** *tradeable permits*; and **[T]**: *pollution taxes.* We characterize political equilibrium as an evolving policy compromise between special-interests, representing polluters, and the electorate. We identify three factors that play a key role in explaining the recent trend in instrument choice: increasingly ambitious environmental targets, learning-by-doing driven reductions in transaction costs associated with permit trading, and (abatement) cost-reducing technological progress.

Keywords: Instrument choice; political economy; environmental policy.
JEL classification: D78; H23; Q28.

Non-Technical Abstract

In the past 15 years, the conduct of environmental policy has changed significantly in all major Western democracies. This is reflected by increasingly ambitious environmental targets, but also in the instruments used to achieve these targets. Traditionally, environmental policy has been based on so-called command-and-control instruments, such 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, a remarkable shift towards the use of incentive-based instruments, such as environmental taxes and tradeable pollution permits, has taken place in recent years. Many European countries, notably the Scandinavian countries, have increasingly shifted attention towards environmental taxes, while the trend in the U.S. has gone in the direction of tradeable permits.

This paper proposes a positive theory of environmental instrument choice that can help us understand these tendencies. The theory is based on the notion that the choice of environmental policy instrument derives from the activities of politicians, who value political office, voters, who attempt to control the behavior of politicians by making reelection contingent on past behavior, and a special-interest group (an industry lobby group), which seeks political influence by providing monetary rewards to politicians (bribes or campaign contributions). What we have in mind is a democratic society that seeks to lower the level of pollution from industrial production to a pre-specified target. The target can be implemented by one of three instruments: [**Q**]: *quantity controls*; [**P**]: *tradeable permits*; and [**T**]: *pollution taxes.* Voters always support [**T**] because of the extra revenue. The industry lobby group may support either of the three instruments depending on the stringency of the target.

The transition from command-and-control to incentive-based policy instruments can be understood as a natural consequence of more ambitious environ-

mental targets and/or (abatement) cost-reducing technological progress. The intuition is appealing. As environmental targets become more strict, the industry lobby group, representing the interests of the polluting industry, becomes more and more interested in cost-efficiency, and starts supporting tradeable permits or even pollution taxes. This eventually moves the economy away from quantity controls and sets of a three-stage transition: [**Q**] to [**P**] to [**T**] or, if transaction costs are high, a two-stage transition: [**Q**] to [**T**]. In the face of cost-reducing technological progress, the industry lobby group becomes generally speaking less concerned with the choice of instrument, and its willingness to pay for either quantity controls or tradeable permits diminishes. As a result, politicians start paying more attention to voters, and the economy moves towards pollution taxes.

The different paths observed in the European democracies, [**Q**] to [**T**], and the U.S., [**Q**] to [**P**], can best be understood as a result of the *interaction* between cross-country differences in political institutions and the general trend towards stricter environmental targets and lower abatement costs. Broadly speaking, the European transition to [**T**] and the U.S. transition to [**P**] can be understood as a reflection of differences in the role played by lobby groups, with U.S. politicians being more responsive to special-interests than their European counterparts. In addition, the cost of operating a permit market is likely to fall over time once it gets going due to learning-by-doing. This increases the industry lobby's willingness to pay in support of [**P**], and suggests that [**P**] becomes a relatively persistent phenomenon and that the transition to [**T**], triggered by continuously falling abatement costs and more ambitious environmental targets, can be delayed or circumvented altogether. Interestingly, if there exists important spill-over effects whereby countries that have not themselves experimented with permit trading can learn from those which have, a transition from [**T**] to [**P**] is possible. Perhaps that is what is happening in Europe where some countries (such as Denmark and the UK) are currently setting up markets and the Commission of the European Union is contemplating a market for tradeable greenhouse gas pollution permits from 2005.

The paper is related to a small but growing literature on the political economy of instrument choice in environmental policy, such as Buchanan and Tullock (1975), Dijkstra (1999), and Boyer and Laffont (1999). Our model can be seen as a generalization of the theory of environmental regulation developed by Buchanan and Tullock (1975) in the sense that we expand the set of instruments by [**P**], and model, formally, the political conflict between polluters and taxpayers. The main innovation of the model, however, is the analysis of the dynamic transition between political equilibria – something that can help us understand why the status of incentive-based instruments has risen in the political arena in many democracies.

The paper has 9 sections. In section 1, we introduce the paper and summarize the main results. In section 2, we briefly review recent trends in environmental policy, and provide an overview of the latest developments in Europe and the U.S. In section 3, we survey previous theoretical contributions to the literature on the political economy of instrument choice. In section 4, we discuss the economic structure of our model. In section 5, the nature and impact of the three policy instruments are set out. In section 6, we describe political decision making. We characterize political equilibrium in section 7, and analyze the dynamic transition from one equilibrium to another. In section 8, we interpret the results, and in section 9, we conclude.

List of Content

List of Figures

List of Tables

1 Introduction

In the past 15 years, the conduct of environmental policy has changed significantly in all major Western democracies. This is reflected by increasingly ambitious environmental targets, but also in the instruments used to achieve these targets. Traditionally, environmental policy has been based on so-called command-and-control instruments, such 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 (see, e.g., Hahn, 1989), a remarkable shift towards the use of incentive-based instruments such as environmental taxes and tradeable pollution permits has taken place in recent years. Many European countries, notably the Scandinavian countries, have increasingly shifted attention towards environmental taxes (OECD, 1997), while the trend in the U.S. has gone in the direction of tradeable pollution permits (Svendsen, 1998; Ellerman et al., 2000). Recently the interest in tradeable pollution permits has increased also in Europe where the Commission of the European Union, having failed to gain support for a common CO_2 tax, is contemplating setting up a market for greenhouse gas emissions from year 2005 (Elkins and Speck, 2000; CEU, 2001). These trends are undoubtedly the outcome of complex economic and political forces.

This paper proposes a positive theory of environmental instrument choice that is designed to illuminate these tendencies and to highlight at least some underlying forces. To accomplish this, we need more than a static theory of instrument choice. We need a dynamic theory that can explain the *change* in equilibrium policy over time. With the exception of Boyer and Laffont (1999) this dynamic aspect of environmental instrument choice has not been considered much in the literature. The main contribution of the paper is to provide a theoretical framework that can be used to characterize the transition from political equilibria with command-and-control regulation to equilibria with incentive-based policy instruments as the outcome of an evolving political compromise between special-interests and the electorate. The precise nature of the compromise depends on many factors, but we identify three which we believe to be of particular importance: increasingly ambitious environmental targets, (abatement) cost-reducing technological progress, and learning-by-doing driven reductions in the transaction cost of trading pollution permits.

Our model has a number of features that should be highlighted at the outset. First, we concentrate on the choice of instrument, taking the environmental target to be achieved as predetermined. This simplification is motivated by the fact that countries often enter international agreements (such as the Kyoto Protocol) that commit them to certain targets, but leave it up to the individual country to decide how to achieve these targets. Likewise, it is not uncommon that a domestic target is, explicitly or implicitly, chosen before deciding on the specific means to achieve it. Examples of this include the U.S. Acid Rain Program (see Stavins, 1998: p 77) as well as the national greenhouse gas reduction targets introduced by the UK and other European countries in the mid 1990s (see Marshall, 1998).

Second, to achieve the environmental target, we assume that the government has access to three policy instruments; these are [**Q**]: *quantity controls*; [**P**]: *tradeable permits;* and [**T**]: *pollution taxes.* We take the set of instruments as given, and choose the two incentive-based instruments to mirror the type of policy instruments actually used in Europe and the U.S. The tradeable permit instrument, for example, allocates the permits for free (as in the U.S. pollution trading programs), and we recognize that permit trading is associated with transaction costs (Stavins, 1995). The pollution tax is levied on emission and recycles, at least partly, the tax revenue to the general public (as, for example, in Norway and Sweden).

Third, it is well-known that the two incentive-based instruments are more efficient that quantity controls (Baumol and Oates, 1988: chapter 11-12; Milliman and Prince, 1989). This and the different financial implications of the three instruments play a key role in our political economy model of instrument choice. Environmental quality, on the other hand, is the same under all three instruments and does not play a role. We focus on the conflict between the electorate (the general public) and organized special-interests. Following previous work on policy compromise in a dynamic democracy (Aidt and Dutta, 2001), we assume that this conflict of interest is resolved in a political process where voters can reward politicians by reelection (if they implement **[T]** and recycle the revenue) and where an industry lobby group, representing polluters, can "bribe" politicians into implementing either **[Q]** or **[P]**.[1] We characterize political equilibrium in terms of economic and political fundamentals, such as abatement and transaction costs, the environmental target, and political institutions. In a static sense, our model can be seen as a generalization of the theory of environmental regulation developed by Buchanan and Tullock (1975) as we expand the set of instruments by **[P]** and model, formally, the political conflict between polluters and taxpayers. The main innovation of the model, however, is elsewhere. To understand why the status of incentive-based instruments has risen in the political arena, it is necessary to explain the *change* in political equilibrium from **[Q]** to **[P]** or **[T]**. To this end, we develop a dynamic theory of instrument choice that can be used to characterize the transition process.

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[1] Our model ignores the potentially important role played by environmental lobby groups. The first priority of environmental lobby groups surely is to protect the environmental, and they are, to a first approximation, only concerned with the choice of policy instrument insofar as the choice *itself* has implications for environmental quality. In our model, the environmental target is exogenously given, and can be acheived by any of the three instruments. Within this context, environmentalists are therefore indifferent to the choice of instrument, and we feel justified in not granting them an independent role in the model. In an extented model, in which the target is endogenous, organized environmentalists would play an important role.

We show that the transition from command-and-control to incentive-based policy instruments can be understood as a natural consequence of more ambitious environmental targets and/or cost-reducing technological progress. The intuition is appealing. As environmental targets become more strict, the industry lobby group becomes more and more interested in cost-efficiency, and starts supporting [**P**] or even [**T**]. This eventually moves the economy away from [**Q**] and sets of a three-stage transition: [**Q**] to [**P**] to [**T**] or, if transaction costs are high, a two-stage transition: [**Q**] to [**T**]. In the face of cost-reducing technological progress, the industry lobby group becomes generally speaking less concerned with the choice of instrument, and its willingness to pay for either [**Q**] or [**P**] diminishes. As a result, politicians start paying more attention to voters, and the economy moves towards [**T**].

The different paths observed in the European democracies, [**Q**] to [**T**], and the U.S., [**Q**] to [**P**], can best be understood as a result of the *interaction* between cross-country differences in political institutions and the general trend towards stricter environmental targets and lower abatement costs. Broadly speaking, the European transition to [**T**] and the U.S. transition to [**P**] can be understood as a reflection of differences in the role played by lobby groups, with U.S. politicians being more responsive to special-interests than their European counterparts. In addition, the cost of operating a permit market is likely to fall over time once it gets going due to learning-by-doing. This increases the industry lobby's willingness to pay in support of [**P**], and suggests that [**P**] becomes a relatively persistent phenomenon and that the transition to [**T**], triggered by continuously falling abatement costs and more ambitious environmental targets, can be delayed or circumvented altogether. Interestingly, if there exists important spill-over effects whereby countries that have not themselves experimented with permit trading can learn from those which have, a transition from [**T**] to [**P**] is possible. Perhaps that is what is happening currently in Europe.

The rest of the paper is organized as follows. In section 2, we briefly review recent trends in environmental policy. In section 3, we survey previous theoretical contributions to the literature on the political economy of instrument choice. In section 4, we discuss the economic structure of our model. In section 5, the nature and impact of the three policy instruments are set out. In section 6, we describe political decision making. In section 7, we characterize political equilibrium, and analyze the dynamic transition from one equilibrium to another. In section 8, we interpret the results, and in section 9, we conclude.

2 Emerging Incentive-based Approaches to Environmental Regulation

In this section, we briefly review recent trends in the use of policy instruments in environmental regulation in Europe and the U.S. The picture is clear: the tendency is to move away from [**Q**]; Europe towards [**T**] and perhaps towards [**P**], and the U.S. towards [**P**].

- **Environmental taxation in Europe.** The use of environmental taxes has increased during the past 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 such as the UK and France are currently implementing environmental taxes to help achieve the reduction targets for greenhouse gas emissions set out in the Kyoto Protocol and by domestic targets, while Germany and Italy have already introduced CO_2 taxes. Measured against GDP, the revenue generated by environmental taxes[2] increased from 2.1% to 2.9% between 1980 and 1997 in EU15, while the share in total tax revenue grow by about 14% during the

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[2] 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 as a Percentage of Total Tax Revenue, 1980-97.

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

Source: European Environmental Agency (2000)

same period (European Environmental Agency, 2000). Table 1 shows the contribution to total tax revenue from three types of environmental taxes: energy taxes, transport taxes, and pollution taxes. Energy and transport taxes, typically, have an environmental rationale, and are in many cases 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 account for the lion's share of the revenue generated.

The specific design of environmental tax programs with respect to tax base, revenue use, and exceptions differs from program to program. Following Cansier and Krumm (1997), we can, however, categorize pollution tax programs into two broad categories, referred to as the "Pure-Tax-Approach" (PTA) and the "Tax-cum-Earmarking" (TCE) approach. PTA refers to a situation in which the incentive effect of the tax is the key motivating factor behind the program, and the tax revenue contributes to the public budget without being tied to specific purposes. This leaves open the possibility of recycling the revenue as reductions in distortionary taxes and thus 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. 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 1.1 and 1.2 summarize key characteristics of air pollution tax programs currently in use in Europe. We notice that PTA is used in Sweden, Norway, the Netherlands, and Finland, while TCE is prevalent in Denmark, France, and Austria. All countries have introduced some exemptions for CO_2 taxes. In conclusion, the use of environmental taxes, in particular (differentiated) energy taxes, but also pure pollution taxes, have become popular in many European countries during the 1990s. In some countries, far-reaching green tax reforms have been introduced, while in others environmental taxes have been accompanied by earmarking and preferential treatment of certain sectors. The later is most likely responsible for the fact that CO_2 targets have not been meet in many of the countries that have introduced CO_2 taxes (Daugbjerg and Svendsen, 2001).

- **Pollution permit markets.** Since the mid-70s, a number of tradeable permit systems has been used in the U.S. to control air and water pollution. Key features of eight of these programs are summarized in Table 1.3, adapted from Svendsen (1998, Table 4.1). Five of the programs are concerned with air pollution, either at the state level or at the national level, and the remaining three are concerned with water pollution. Some of these programs were successful in reducing pollution at a relatively low cost (e.g., the lead trading program), while others, such as the Emission Trading Program and the Fox River Waste Water Program, were not (see Hahn, 1989). For example, in the Emission Trading Program, many (potential) participants decided not to trade or focussed on internal trades; thereby reducing the scope for cost savings. This suggests that the transaction costs implied by the design of some of these programs were too high to make a viable market possible. This is, however, not entirely surprising as the early programs grow out of a command-and-control tradition and persevered many of the features associated with traditional command-and-control regulation. 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 trading 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 plants. The permits are allocated to the owners of the affected power plants on a yearly basis according to specific rules, primary depending on past emission levels and fuel use. The permits can be saved for future use, and can be traded freely throughout the U.S. in both private markets and in a small annual auction. The performance of the program has been evaluated in detail by Ellerman et al. (2000).[3] They conclude that it has been successful: environmental targets have 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 command-and-control regulation (Stavins, 1998, p. 71).

While air pollution permit trading has largely been associated with the U.S., similar programs are now being adopted in some European countries, such as the UK and Denmark, to help control CO_2 emissions (Ekins and Speck, 2000). Also at the international level, the interest in pollution permit trading is on the rise. For example, one of the so-called flexibil-

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

ity mechanisms set out by the Kyoto Protocol envisions an international market for tradeable CO_2 emissions allowances (see Grubb, 2000). Finally, the European Union is contemplating setting up a market for tradeable greenhouse gas emission permits by 2005 (CEU, 2000).

3 Positive Theories of Instrument Choice

There is a small but growing literature on the political economy of instrument choice in environmental policy. The classical paper in the area is Buchanan and Tullock (1975). They show that a competitive industry that generates pollution prefers a pollution quota system to a pollution tax, and argue that this preference is likely to prevail politically.[4] The logic is appealing. The quota system enforces a reduction in total industry output, and raises profits. Taxes, on the other hand, reduce industry profits, and the financial losses do not disappear until a sufficient number of firms has relocated to other sectors. While "*(t)hose who anticipate benefits from the utilization of the tax revenues, whether from the provision of publicly supplied goods or from the reduction in other tax levies, should prefer the tax alternative and they should make this preference known in the political process*" [p. 142], Buchanan and Tullock go on to argue that the supporters of the tax alternative will be politically weak relative to the small, well-organized group of firms and therefore lose out. The political conflict between organized industry interests and of society, represented by a majority of the electorate, is also key to our argument, but we take the analysis one step further. We model explicitly the process by which a compromise between the two parties is reached, and identify the circumstances under which voters prevail,

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[4] 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 prefer pollution standards that are tougher for new firms than for old ones to other types of regulation. Hence, workers and capitalists in a particular industry might have a common interest in supporting command-and-control instruments.

thereby explaining the emergence of incentive-based instruments in political equilibrium. In addition, Buchanan and Tullock compare [**Q**] to [**T**]. Including [**P**] in the menu of options introduces an important, new element.[5] We show that the industry, typically, argues in favor of [**P**], preferring this to [**Q**] when the environment target is sufficiently demanding and the transaction cost of running a permit market is not prohibitive. The electorate prefers [**T**], and can enforce a move to this instrument if there is sufficient (abatement) cost-reducing technological progress.

Dijkstra (1999, chapters 8 and 9) analyses the choice between command-and-control 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 most-favored policy implemented. He finds that incentive-based instruments are chosen with low probability in equilibrium when they are supported by a relatively large group of supporters with a low per capita stake. This formalizes the hypothesis of Olson (1965) that smaller groups are more likely to have political voice and leads to the conclusion that tax instruments ([**T**]) are rarely chosen in political equilibrium. Dijkstra (2000) shows that this tendency is preserved in contests where both the choice of instrument and the distribution of the revenue from tax instruments are subject to rent-seeking.

These theories are designed to explain why we observe [**Q**] despite the fact that [**T**] is available. They do not directly explain why we may observe a shift away from [**Q**] to more efficient policy instruments, [**T**] or [**P**]. This question is addressed formally by Boyer and Laffont (1999). They formulate the problem as one of incomplete contracting under asymmetric information, and ask when a society could benefit from constitutional constraints on the set of policy instruments. To be specific, they consider a monopolist, who has private information

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

about the cost of a polluting project. Due to the asymmetry in information, incentive compatibility forces the politician in charge of regulating the monopoly to leave some rent to the firm. The politician's scope for diverting part of this rent to his 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. The monopolist resists $[\mathbf{T}]$ for distributional reasons. Boyer and Laffont 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.

Our approach differs from this in several ways. First, we take the set of policy instruments, $\{[\mathbf{Q}], [\mathbf{P}], [\mathbf{T}]\}$, as given, and do not consider the possibility of constitutional constraints. Instead, we evaluate when and whether each instrument is part of a *political equilibrium.* Second and more importantly, we offer a dynamic model that is well-suited to study the evolution of political equilibrium over time and thus to explain why the choice of policy instrument changes. Third, citizens vote, and this is explicitly accounted for in our analysis.

4 The Economy

Economic activity and policy choices take place over infinite discrete time, $t = 0, 1, 2, \cdots$. Citizen-consumers are identical and live for ever. Their instantaneous utility is defined over the consumption of a numeraire good y_t, a produced good x_t, a public good g_t, and environmental quality, $1 - e_t$, where $e_t \in [0, 1]$ is emission of pollutants. The total utility of a representative citizen-consumer is

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

where $u(.)$ and $u_e(.)$ are increasing and strictly concave functions, and β is the discount rate. The representative citizen-consumer is endowed with $\bar{y}$ units of the numeraire good each period, and the price of good x is denoted p_t. The public good is, where applicable, financed by the revenue generated by a pollution tax. For the time being we maintain the assumption that the tax revenue is recycled fully to citizen-consumers.[6] This is clearly an extreme assumption, and we shall relax it in due course.

A continuum of firms, of measure 1, produce good x. Each firm produces one unit at zero marginal cost. Total production is therefore $x_t = 1$, implying that $p_t = p = u'(1)$. Production of x pollutes the environment, and in the absence of regulation, each firm emits one unit of pollution each period, such that aggregate emission is $e_t = 1$. Firms can lower emissions at a cost. Let $a_{it} = 1 - e_{it}$ be the abatement level of firm i in period t. The abatement cost function is[7]

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

We assume, in addition, that

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

Differences in abatement costs among firms are captured by θ_i. A firm with a low θ_i has high abatement costs and *vice versa*. Technological progress ($A_{t+1} \geq$

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[6] We do not explore the possibility that the tax revenue can be used to reduce distortionary taxes on labor and capital. As shown by Goulder et al. (1996) this may underestimate the efficiency gains of [**T**] by as much as 25%.

[7] The use of a quadratic cost function is not restrictive. What is important is that the abatement cost function is convex. Convexity implies that the efficiency gain associated with [T] or [P] increases with abatement requirements.

$A_t > 0$) reduces abatement costs over time. The reduction is proportional for all types of firms. The distribution of abatement costs is stationary over time, and represented by the distribution function $F(\theta)$ with support on the interval $[\theta_L, \theta_H]$. Two characteristics of F are important for the analysis, namely, 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.

5 Environmental Regulation

We consider a society that has committed to reduce emissions according to a predetermined target, denoted $\bar{e}_t \in (0, 1]$, and $\bar{e}_{t+1} \leq \bar{e}_t$. The target $\bar{e}_t$ can be implemented by means of one of three policy instruments, [**Q**], [**P**], or [**T**], as discussed in the introduction. The government cannot observe θ_i for individual firms, but knows A_t as well as the distribution $F(\theta)$. Before we characterize the instrument choice in political equilibrium, we describe the impact of each instrument on the behavior and profitability of firms.

5.1 Quantity Controls: [Q]

The government cannot tailor quantity controls appropriately to the conditions of each firm, and we assume that it therefore uses a *uniform* emission quota system. The quota issued to each firm is valid for one period, and allows the holder to emit up to $\bar{e}_t$ units. To avoid exceeding the quota, abatement effort of $\overline{a}_{it} = 1 - \bar{e}_t$ per firm is required, and the resulting per period profits are

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

Total industry profits are[8]

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

The instrument [**Q**] does not achieve abatement at least cost, as the marginal cost of abatement is higher for low-θ firms than for high-θ firms.

5.2 Tradeable Permits [P]

As an alternative to quantity controls, the government can issue tradeable permits. We assume that each firm is given permission to pollute $\bar{e}_t$ units free of charge. Firms are allowed to trade permits among themselves. The permits are valid for one period only and cannot be saved. Organizing and maintaining an effective permit market is costly for numerous reasons: search and information collection is costly; bargaining and decision costs can be high as can monitoring and enforcement costs (Stavins, 1995). We capture this aspect of permit trading by assuming a fixed cost of trading, which is shared by all participating firms.[9]

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[8] To insure that industry profit is positive, we assume that $U'(1) \geq \frac{1}{2A_0\theta_L}$. This condition is sufficient to ensure non-negative profits for all $\bar{e}_t > 0$ and under all three instruments in the absence of transaction costs. We do not allow entry. Our results hold qualitatively in a setting in which there is free entry and the marginal firm makes no profit, but the analysis becomes much more complex as high-cost and low-cost firms might disagree on which policy instrument to support.

[9] This is slightly different from a situation where firms choose whether or not to pay the cost and trade, but the difference is not essential for our results. 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 if the deviation from the least cost allocation is substantial.

The cost of trading may be falling over time for many reasons. We focus on two and assume that the cost of trading is given by $\phi_t = \frac{\phi}{\alpha_t A_t}$ where $\phi \geq 0$. First, technological progress related to advances in telecommunication and better accounting systems and procedures to track emission are likely to reduce the cost of running a permit market. For simplicity, we shall assume that technological progress reduces transaction and abatement costs at the same rate.[10] Second and more importantly, once a market has been established, the participating firms learn from the experience, and the reduction in trading costs is likely to accelerate due to learning-by-doing ($\alpha_t \geq \alpha_{t-1} > 0$).

Suppose permits are traded at the price q_t in period t. Firm i chooses its emission level to maximize its current profit

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

Profits are maximized at[11]

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

Market clearing implies

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

or

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

Substituting in the expression for profits yields

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

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[10] This assumption can be relaxed without affecting the qualitative nature of our results but only at the cost of greater complexity. Moreover, in the absence of any precise empirical evidence on the relative speed of cost reductions, it seems as good an assumption as any.

[11] To rule out corner solutions in which the most efficient firms decide to stop emitting, we assume that $\frac{\theta_H}{A_0 \mu} > 1$.

Total industry profits are

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

Comparing equations (2) and (4), we obtain the following result about industry profits under [**Q**] and [**P**].

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

$$\bar{e}_t \leq \varepsilon_{1t} \equiv 1 - \sqrt{\frac{2\phi}{\Delta \alpha_t}}$$

In the absence of transaction costs ($\phi = 0$), the industry makes more profit under [**P**] than under [**Q**]. The difference represents a pure efficiency gain, measured by $(1-\bar{e}_t)^2\frac{\Delta}{2}$ in the aggregate. Lemma 1 states the condition under which the efficiency gain outweighs the transaction cost of permit trading. We note that [**Q**] yields more profit than [**P**], if the target, $\bar{e}_t$, is sufficiently lax. In the initial phase of a program of gradual abatement, firms, therefore, favor control-and-command regulation.

5.3 Pollution Taxes [T]

As an alternative to the permit system or to quantity controls, the government can levy a tax on emissions, at the rate τ_t.[12] Firm i chooses e_{it} to maximize its profit

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

knowing that it has to pay $\tau_t e_{it}$ in taxes if it emits e_{it} units of pollution. The first order condition yields

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

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[12] We consider a simpler tax policy than Boyer and Laffont (1999), where firms face a tax schedule $T(e_{it})$. Our simplification is harmless because $\bar{e}_t$ is exogenous.

To reduce total emission to $\bar{e}_t$, the tax rate must satisfy

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

Substitution yields the expression for firm profits

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

Industry profits are

$$\begin{aligned} \bar{V}_t(\mathbf{T}) &= \bar{V}_t(\mathbf{P}) + \phi_t - \frac{\bar{e}_t(1-\bar{e}_t)}{A_t\mu} \qquad (6) \\ &= p - \frac{(1-\bar{e}_t)^2}{2\mu A_t} - \frac{\bar{e}_t(1-\bar{e}_t)}{\mu A_t}. \end{aligned}$$

We note that **[P]** and **[T]** achieve exactly the same least cost allocation of abatement, and firms that emit more than average pay the same price for additional units of emission under the two systems. The difference between the two systems is their financial implications. Under the tax system firms have to pay for all the units they emit, and the revenue is transferred to voters. Under the permit system, firms do not pay for unabated emission within their allowance, and firms that decide to abate more than required can sell their permits, implying a transfer from high-cost firms to low-cost firms. By direct evaluation of equation (6), we obtain the following result about industry profits under **[P]** and **[T]**.

Lemma 2 *Let* $\bar{e}_t < 1$ *and* $\phi\mu \leq \frac{1}{4}\alpha_0$*. Define* $\varepsilon_{2t} \equiv \frac{1}{2} - \sqrt{\frac{1}{4} - \frac{\phi\mu}{\alpha_t}}$*. Industry profits are higher under [**P**] than under [**T**] if and only if*

$$\varepsilon_{2t} < \bar{e}_t < 1 - \varepsilon_{2t}.$$

Lemma 2 establishes that **[P]** is preferred to **[T]** unless $\bar{e}_t$ is either close to 0 or to 1.[13] >From a financial point of view, the difference between the two systems is the total tax bill, $\bar{e}_t(1-\bar{e}_t)/\mu A_t$, which under the permit system

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[13] If the condition $\phi\mu < \frac{1}{4}\alpha_0$ fails, the transaction cost of permit trading is so large that $[T]$ is always preferred to $[P]$.

Table 2: Policy Instruments and Industry Profits

Policy **[S]**	Profits $\bar{V}_t(S_t)$
[Q]	$p - \frac{(1-\bar{e})^2}{2\eta A}$
[P]	$p - \frac{(1-\bar{e})^2}{2\mu A} - \frac{\phi_0}{A\alpha}$
[T]	$p - \frac{(1-\bar{e})^2}{2\mu A} - \frac{\bar{e}(1-\bar{e})}{\mu A}$

accrues to the industry and under the tax system accrues to the government (to citizen-consumers).[14] If the environmental standard is extremely lax, or extremely stringent, the tax bill is too small to compensate for the fixed transaction cost (ϕ_t). In the former case, the tax rate is negligible, and in the latter, the tax base is negligible.

5.4 Profits and Instruments

Table 2 summarizes the industry profits associated with each policy instrument. Proposition 1 establishes that each instrument achieves the highest profit for some emission target.

Proposition 1 *Assume* $0 < \phi < \frac{2\eta}{\mu}\frac{\mu-\eta}{(\mu+\eta)^2}\alpha_0$. *There exists a* ε_H *and a* ε_L *such that* $0 < \varepsilon_L < \varepsilon_H < 1$ *for all* t *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* $\varepsilon_L \leq \bar{e}_t < \varepsilon_H$*;*

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[14] Under [**T**] the property right to the revenue rests with voters (the public), while under [**P**], it rests with the industry (the polluter). The two instruments can, therefore, be interpreted as two extremes along a continuum of policy regimes with joint property rights. If the tax revenue were to be reimbursed to industry, then [**T**] would become much like [**P**]. Likewise, if, as discussed by Grafton and Devlin (1996), the government combines [**P**] with a charge that extracts (part of) the rent from the industry, then [**P**] becomes much like [**T**].

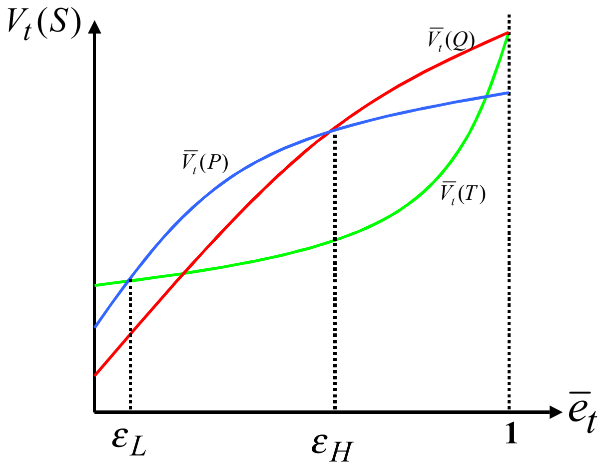

Figure 1: The emission target and industry profits under the three instruments ($\phi > 0$)

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 $\bar{V}_t(\mathbf{P}) \geq \bar{V}_t(\mathbf{Q})$ whenever $\bar{e}_t \leq \varepsilon_{1t}$, and from Lemma 2 that $\bar{V}_t(\mathbf{T}) > \bar{V}_t(\mathbf{P})$ whenever $\bar{e}_t < \varepsilon_{2t}$. Comparing equations (2), (4) and (6), we obtain

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

The condition $\phi < \frac{2\eta}{\mu} \frac{\mu - \eta}{(\mu+\eta)^2} \alpha_0$ implies that $\varepsilon_{2t} < \varepsilon_3 < \varepsilon_{1t}$ for all t, so that $\bar{V}_t(\mathbf{Q}) \geq \bar{V}_t(\mathbf{P}) \Rightarrow \bar{V}_t(\mathbf{Q}) \geq \bar{V}_t(\mathbf{T})$. It suffices to set $\varepsilon_L = \varepsilon_{2t}$ and $\varepsilon_H = \epsilon_{1t}$ ■

The effect of the instrument choice on industry profits can be understood quite intuitively, and is illustrated in Figure 1. The Figure shows industry profits under the three instruments as a function of the environmental target for given A_t and α_t. In the absence of transaction costs, $\bar{V}_t(\mathbf{P})$ always exceeds $\bar{V}_t(\mathbf{Q})$ and $\bar{V}_t(\mathbf{T})$, as $\varepsilon_L = 0$ and $\varepsilon_H = 1$ whenever $\phi = 0$ for all t. Small transaction costs change this. First, suppose that the environmental target is lax, i.e., $\bar{e}_t \simeq 1$. Due to the gains associated with achieving allocative efficiency, permit trading, [**P**], always has an advantage over quantity controls, [**Q**], but the advantage is small relative to the fixed cost of trading when little abatement is required. This explains $\bar{V}_t(\mathbf{Q}) > \bar{V}_t(\mathbf{P})$. Second, suppose the environmental target is strict, i.e., $\bar{e}_t \simeq 0$. Under these circumstances, $\bar{V}_t(\mathbf{T}) > \bar{V}_t(\mathbf{P})$. This is somewhat counterintuitive because taxes constitute a net transfer from the industry to citizen-consumers. It is caused by a combination of the fixed transaction cost of permit trading and the "Laffer curve" of the pollution tax. The total pollution tax bill is proportional to $\bar{e}_t(1 - \bar{e}_t)$. When the emission target is strict, $\bar{e}_t$ is near zero, and firms pay very little in tax. Hence, the tax bill is small relative to the fixed transaction cost of permits trading, as well as relative to the cost of allocative inefficiency associated with quantity controls. This explain why profits are higher under [**T**] than under either of the two other instruments when $\bar{e}_t \simeq 0$.

Proposition 1 has important implications for the policy preferences of the industry. To see this, consider the following thought experiment. Suppose the government signs a binding international agreement to lower emissions to zero over, say, 10 years ($\bar{e}_{10} = 0$) starting from a situation of uncontrolled pollution ($\bar{e}_1 = 1$). The industry supports the policy instrument that maximizes aggregate profits. As the emission target $\bar{e}_t$ falls from 1 to 0, it transits from above ε_H to below ε_L. In the initial phase, $\bar{e}_t > \varepsilon_H$, and [**Q**] maximizes total industry profit. Accordingly, the industry initially supports this instrument. This is similar to Buchanan and Tullock (1975), although the underlying logic is different. In our model, the industry prefers [**Q**] because the efficiency gain is insufficient to outweight the transaction cost of permit trading. As the target is gradually tightened, there comes a time, $\tilde{t}$, such that $\bar{e}_{\tilde{t}}$ falls below ε_L, and the industry supports a switch to [**T**], as predicted by Boyer and Laffont (1999). In the intermediate phase, the industry's preferred policy instrument is [**P**]. An implication, then, is that we should observe societies in which the government is captured by industry interests passing through the **[P]** phase, provided they face similar transaction and abatement costs. Hence, within the framework of our model, the Stigler-Peltzman theory of distributive politics (Stigler, 1971) predicts a three stage transition: **[Q]** to **[P]** to **[T]**. This may be consistent with what we have observed in the U.S. (the transition form **[Q]** to **[P]**), but cannot explain why Europe has moved directly from **[Q]** to **[T]**, nor why the U.S. has not move on to **[T]**.

6 The Political Market

We imagine that the instrument choice is an evolving compromise among the interests of politicians, of voters, who has the power to dismiss elected politicians, and of special-interest groups, who are willing to pay to see their preferred policy implemented, and therefore can, if necessary, compensate politicians for the loss of office. Following earlier work (Aidt and Dutta, 2001), the political process is modeled as a dynamic democracy with the following key elements:

1. **Repeated elections and performance voting.** Voters delegate decision making power to politicians in elections. We assume that citizens-consumers hold a majority of the electorate. 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 special-interests (see below). Voters observe policy implementations and hold politicians responsible for their choices 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. At the beginning of each period, voters announce an election rule, $\eta_t(S_t)$, which specifies whether or not the incumbent politician is being reelected as a function of the policy, $S_t \in \{\mathbf{Q}, \mathbf{P}, \mathbf{T}\}$, implemented

during the current term of office. Formally, the election rule is a mapping from $\{\mathbf{Q}, \mathbf{P}, \mathbf{T}\} \rightarrow \{0, 1\}$ where $\eta_t(S_t) = 1$ indicates that the incumbent is reelected, and $\eta_t(S_t) = 0$ that he is not and a challenger enters office. From the analysis in section 5, we know that voters prefer $[\mathbf{T}]$ to either $[\mathbf{Q}]$ or $[\mathbf{P}]$ because of the revenue effect.[15] It follows immediately that they employ the following stationary election rule:

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

2. **Lobbying activities**. It is clear from section 5 that firms have a strong interest in the instrument choice. 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 internally among the members.[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 (1997). We think of these payments as benefits that occur to the politician personally, and a natural interpretation is that they represent bribes but other interpretations are possible. The important point to stress, however, 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 "under-performing" politician. Formally, a lobbying strategy is a payment function, $b_t(S_t)$, that maps the

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[15] Except when $\bar{e}_t = 0$ or $\bar{e}_t = 1$ where they are indifferent among the three instruments.

[16] We have chosen the formulation with one industry lobby group for simplicity. The model can be extended to the case where different segments of the industry (say the clean and the dirty firms) form separate lobby groups, but the additional complications do not add essential new insights.

policy choice made by the incumbent politician in a given period into a monetary payment. The lobby group discounts the future at rate β, and has payoff $\sum_{t=0}^{\infty} \beta^t \left(\bar{V}_t(S_t) - b_t(S_t)\right)$.

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 holds office. We assume that m is the same for all politicians. In addition, holding power allows the politician to collect payments from the lobby group. The per-period payoff of an elected politician is

   $$m + b_t(S_t). \tag{8}$$

   We assume that a politician that is voted out of office is never reelected, and will get his reservation utility, normalized to zero. Politicians discount the future at rate β.

The timing of events is as 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. Taking as given the election rule and the payment function, the incumbent politician implements a policy, $S_t \in \{\mathbf{Q}, \mathbf{P}, \mathbf{T}\}$. The lobby group then makes the promised payment, and a new election is held. This sequence of events repeats itself every period, and is summarized in Figure 2.

7 Political Equilibrium

Following Coate and Morris (1999), we define political equilibrium as a Markov perfect equilibrium. We shall analyze how the political equilibrium changes as the key parameters, $\bar{e}_t$, A_t, and α_t evolve over time. However, before we do so,

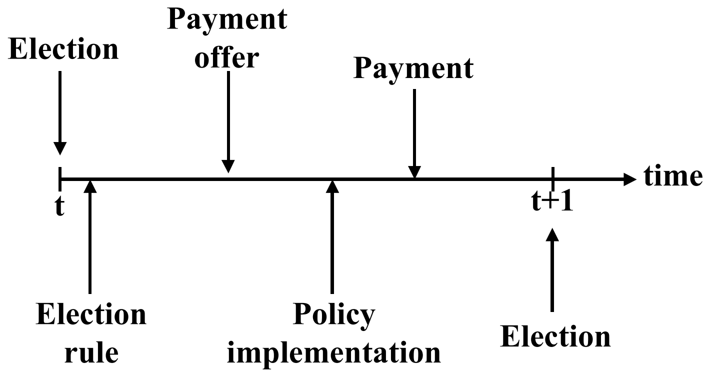

Figure 2: The timing of events.

we characterize the set of stationary political equilibria. To this end, assume that $\bar{e}_t = \bar{e}$, $A_t = A$ and $\alpha_t = \alpha$ for all t. This makes the economy completely stationary and if something is an equilibrium in period t so it is in period $t+i$, $i = 1, ..., \infty$. Proposition 2 summarizes the possible equilibrium configurations.

Proposition 2 *(Stationary Political Equilibrium) Define* $M = \frac{\beta m}{1-\beta}$*. The following stationary policy sequences are implemented in Markov perfect equilibrium:*

1. $\widehat{S} = \mathbf{Q}$ *if* $\bar{e} \geq \varepsilon_H$ *and* $\frac{1-\bar{e}^2}{2A\mu} - \frac{(1-\bar{e})^2}{2A\eta} \geq M$;
2. $\widehat{S} = \mathbf{P}$ *if* $\varepsilon_L \leq \bar{e} \leq \varepsilon_H$ *and* $\frac{\bar{e}(1-\bar{e}) - \frac{\mu\phi}{\alpha}}{A\mu} \geq M$;
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

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

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 group designs $b(S_t)$ to maximize current net benefit. Clearly, the lobby group will never pay for [**T**] as the politician is happy to choose that instrument in the absence of lobbying. Hence, $b(\mathbf{T}) = 0$. Further, from Proposition 1, the lobby group will choose $b(\mathbf{P}) > 0$ only if $\bar{e} \in [\varepsilon_L, \varepsilon_H)$, and similarly $b(\mathbf{Q}) > 0$ only if $\bar{e} \in [e_H, 1)$. If the politician were to implement $S \neq T$, he would lose the next election. Hence, to get him to do so, the lobby group must compensate him 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 $\bar{V}(S) - M \geq \bar{V}(\mathbf{T})$, and chooses $b(S) = 0$ for each S otherwise. The proposition follows by substitution from Table 2 ■

Proposition 2 shows that each of the three policy instruments is politically feasible under appropriate conditions. Voters prefer [**T**] and reelect the incumbent politician only if this instrument is employed (and they get the revenue). To get either [**Q**] or [**P**] implemented, the lobby group has to compensate the incumbent politician for the resulting loss of office, and pay a bribe equal to M – the value of holding office in the future. It is therefore clear that the instrument choice depends i) on the policy preference of the lobby group, and ii) on its willingness to pay relative to M. In contrast to Buchanan and Tullock (1975), we note that the preference of the lobby group does not prevail under all circumstances: even when $\overline{e} > \varepsilon_L$ and the lobby group's most-preferred policy is [**Q**] or [**P**], the equilibrium policy is [**T**] whenever abatement costs are low (A is high) and/or the value of office is high.[17]

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[17] It is clear that [**T**] is the unique equilibrium for $\overline{e} < \varepsilon_L$ as the lobby group prefers that instrument to the two alternatives and would not be willing to pay to see [**Q**] or [**P**]

More generally, the Proposition shows that equilibrium policy depends crucially on underlying economic fundamentals, notably abatement technology, the emission target, and the transaction cost of permit trading. These variables evolve over time causing shifts in the instrument choice. We show, in Proposition 3, how the instrument choice at time t responds to such changes.

Proposition 3 *(Transitional Politics) Let* $\bar{e}_t \leq \bar{e}_{t-1}$*,* $A_t \geq A_{t-1}$ *and* $\alpha_t \geq \alpha_{t-1}$*. At political equilibrium, the stationary policy function,* $S_t = \mathcal{S}(\bar{e}_t, A_t, \alpha_t)$*, characterizes the instrument choice as follows:*

1. $S_t = \mathbf{Q}$ if $\bar{e}_t \geq \varepsilon_H$ and $\frac{1-\bar{e}_t^2}{2A_t\mu} - \frac{(1-\bar{e}_t)^2}{2A_t\eta} \geq M$;
2. $S_t = \mathbf{P}$ if $\varepsilon_L \leq \bar{e}_t \leq \epsilon_H$ and $\frac{\bar{e}_t(1-\bar{e}_t)-\frac{\mu\phi}{\alpha_t}}{A_t\mu} \geq M$;
3. $S_t = \mathbf{T}$ otherwise.

Proof. The proof follows from Proposition 2. Profits $\bar{V}_t(S_t)$ are stationary functions of $\bar{e}_t$, α_t and A_t. This follows from Proposition 1. As before, $[\mathbf{P}]$ is an equilibrium at time t if and only if

$$\bar{V}_t(\mathbf{P}) \geq \bar{V}_t(\mathbf{Q}) \tag{10}$$

and

$$\bar{V}_t(\mathbf{P}) \geq \bar{V}_t(\mathbf{T}) + M. \tag{11}$$

Similarly, $[\mathbf{Q}]$ is an equilibrium at time t if and only if

$$\bar{V}_t(\mathbf{Q}) \geq \bar{V}_t(\mathbf{P}) \tag{12}$$

and

$$\bar{V}_t(\mathbf{Q}) \geq \bar{V}_t(\mathbf{T}) + M. \tag{13}$$

Proposition 3 obtains by substitution of the relevant expressions for $\bar{V}_t(S_t)$ in equations (10), (11), (12) and (13), and by noticing that if one of these conditions fails, then $[\mathbf{T}]$ prevails ■

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implemented.

8 Discussion and Interpretation

Proposition 3 reveals a number of interesting results about transitional politics and environmental instrument choice in a democracy. To bring out the intuition as clearly as possible, we shall focus on one aspect of the transition process at the time, keeping in mind that reality is more complex. We start with the emission target.

- **The emission target ($\overline{e}_t$).** The policy preference of the lobby group depends on the stringency of the emission target (Proposition 1). We can deduce how its willingness to pay in support of [**Q**] and [**P**] changes along equilibrium paths with increasingly stringent emission targets from Proposition 3. How this, in turn, causes shifts in the instrument choice can most easily be understood by means of Figure 3. The Figure shows equilibrium configurations for combinations of A_t and $\overline{e}_t$ for given α_t. In the area marked with the vertical lines, [**P**] is equilibrium, while in the area marked with the horizontal lines, [**Q**] is equilibrium. Outside these two areas, the equilibrium is [**T**]. For relatively lax targets ($\overline{e}_t$ close to 1) and relatively high abatement cost (A_t close to A_0), the industry lobby prefers [**Q**], and is willing to compensated the politician for the loss of office to get it implemented: [**Q**] is the initial equilibrium. As the emission target becomes more ambitious, and more abatement needs to be undertaking, the lobby group becomes more keen on the idea of permit trading as the efficiency gains associated with [**P**] compare more and more favorably with the transaction cost of running the market. When the target falls below ε_H, the equilibrium shifts to [**P**]. As the emission target is further tightened, the lobby group becomes less keen on bribing the politician to implement [**P**] because the financial burden of paying the tax for unabated pollution falls relative to the (fixed) transaction cost of permit trading. At some point when the target falls below ε_L, the equilibrium

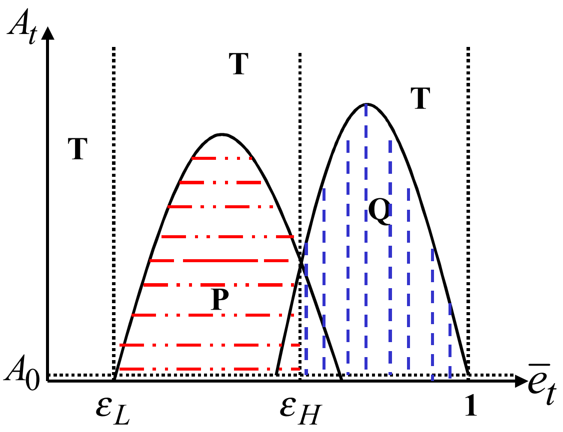

Figure 3: Political equilibrium with low transaction costs.

shifts to [**T**], and politicians start being reelected. We see that a gradual move towards stricter emission targets, e.g., as part of international commitments, can give rise to a three-stages transition from [**Q**] to [**P**] to [**T**]. It is apparent from Figure 3 that a direct transition from [**Q**] to [**T**] is also possible, and more likely when the fixed cost of trading (ϕ) is high and abatement costs are relatively low. Overall, these transitions can explain the observed shift towards incentive-based environmental policy instruments simply by pointing to the fact that environmental targets have become more ambitious.

- **Cost-reducing technology progress (A_t).** Cost-reducing technological progress reduces the profit differentials, $\bar{V}_t(\mathbf{P}) - \bar{V}_t(\mathbf{T})$ and $\bar{V}_t(\mathbf{Q}) - \bar{V}_t(\mathbf{T})$. This in turn reduces the industry lobby group's willingness to pay for [**Q**] or [**P**]. To see the consequences, suppose that $\bar{e}_t = \bar{e}$ and that cost-reducing technological progress occurs at the constant rate, g:[18]

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

>From Figure 3, we see that this leads to a transition from **[P]** to **[T]** if $\bar{e} \in (\varepsilon_L, \varepsilon_H]$ and from **[Q]** to **[T]** if $\bar{e} \in [\varepsilon_H, 1)$. The tax instrument is more likely to be adopted as abatement costs fall. We notice that cost-reducing technological progress cannot by itself explain the differences between Europe and the U.S., but it can help explain why the political acceptability of pollution taxes may increase as firms learn to deal with abatement in more effective ways. Importantly, this implies that tax revenues fall, so that the transition to **[T]** occurs when there are relatively few taxes to collect, and thus when the tax instrument is of less interest from a fiscal point of view.

- **Transaction costs and learning-by-doing (α_t).** One of the reasons why permit trading is costly is the initial lack of experience among traders. Once a market has been established (perhaps as a consequence of increasingly stringent targets), learning will gradually take place, reducing the cost of trading.[19] To see the implications of this, suppose that learning takes place at a constant rate, $\gamma > 0$, when a permit market is operating:

$$\begin{aligned} \alpha_{t+1} &= \alpha_t(1+\gamma) \text{ for } t \text{ such that } S_t = P \\ \alpha_{t+1} &= \alpha_t \qquad\qquad \text{otherwise.} \end{aligned}$$

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[18] The speed of at which new abatement technology is adopted and new innovations are made can be systematically related to the type of environmental regulation that firms are exposed to (see, Milliman and Prince, 1989; Jung et al., 1996). A complete theory would include these feedback effects.

[19] 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 (see Stavins, 1995).

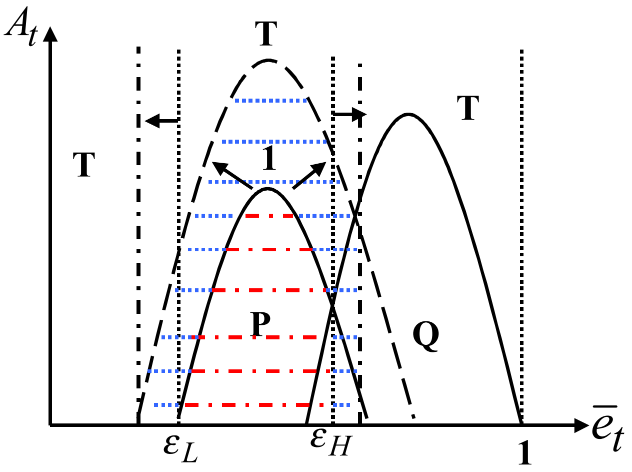

Figure 4: Learning-by-doing and the persistance of permit trading systems

Figure 4 shows how the region in which [**P**] is implemented gradually expands as learning-by-doing reduces transaction costs. This makes [**P**] a persistent phenomenon and can help explain the U.S. experience with permit trading. The initial programs, which entailed only minor deviations from the standard command-and-control approach, started a learning-by-doing process that made the later programs more successful and persistent. To the extent that the learning process has international spill-over effects, the logic of our model suggests that permit trading may become a viable alternative in Europe, predicting a transition from [**T**] to [**P**]. If, for example, Europe is located at point 1 in Figure 4, then, as the learning process in the U.S. reduces the cost of trading at home and abroad, Europe will eventually move towards a permit system.

The conflicting interests of voters, politicians, and lobby groups are mitigated by political institutions, and a policy compromise is reached as discussed above. The political institutions are characterized by a number of features: the ego-rent (m), the time horizon of the politician (β), the degree of voter control ($\eta(.)$), and the ease with which lobby groups can provide monetary incentives to politicians. While political institutions are fairly stable over time, there exist substantial differences between the European democracies and the U.S. The interaction between these cross-country differences on the one hand and the time trends in environmental targets and abatement costs on the other can provide additional insights into the observed differences in the choice of policy instrument.

- **Myopia and corruptibility.** An increase in m, or in β, increases the reelection concern of the incumbent politician. He is more willing to please the electorate and wants to move to [**T**] faster. The lack of term limits in many European democracies increases β, and can explain that more attention is paid to voter interests. Similarly, societies differ in the degree to which politicians can receive compensation from special-interest groups. Limits on campaign contributions, or implementation of anti-corruption legislation, limit $b(S_t)$ and speed up the transition to [**T**]. The importance of special-interest politics and campaign contributions in the U.S. can therefore be seen as a contributing factor in understanding the move from [**Q**] to [**P**] observed there. This effect is reinforced to the extent that low voter turnout in U.S. elections compared to, for example, elections in the Scandinavian countries can be taken as evidence of relatively weak voter control.

- **Single issue elections and electoral accountability.** The cornerstone of our political model is that politicians balance the views of special-interests against those of the electorate. Voters are obviously concerned with many different aspects of policymaking, and environmental policy is only one among many competing political issues. The threat of termination is therefore relatively weak when environmental policy (or more precisely the potential revenue generated by a pollution tax) is of minor importance to voters. In the model, this can be captured by imposing an upper bound on the election rule, $\eta(.) \leq \overline{\eta} < 1$: Voters can only promise to reelect with a certain probability. An implication of this is that the instrument choice, *ceteris paribus*, will reflect more closely the preferences of special-interests in societies in which environmental policy and additional revenue is not of major concern to voters. To the extent that European voters are more "green" than their American counterparts and to the extent that the cost of public funds is relatively low in the U.S., this can help explain why pollution taxes have been relatively successful in Europe.

In our model, we assume that all the revenue from [**T**] is recycled to the electorate. This is an extreme assumption, but one that can easily be relaxed:

- **Reimbursement of tax revenue to industry**. In Europe, the move from [**Q**] to [**T**] has been accompanied by recycling the revenue partly to voters and partly to industry (see, e.g., Cansier and Krumm, 1997; or Ekins and Speck, 1999). In many cases, the actual policy is therefore intermediate between [**P**] and [**T**]. It is relatively simple to show that the industry lobby will block such an intermediate regime less often than the regime where voters get all the revenue. It is more difficult to reconcile partly recycling with the preferences of voters, but may reflect the limited set of control instruments at their disposal. The fact that reimbursement to industry and exemptions for heavy polluters are common practice in almost all the Europe democracies has most likely reduced industry resistance, and is undoubtedly an important factor in explaining the adoption of tax instruments across Europe (see Svendsen et al., 2001).

9 Concluding Remarks

This paper proposes a positive theory of environmental instrument choice that can be used to illuminate the recent trend towards the use of incentive-based policy instruments, such as pollution taxes and tradeable pollution permits. The transition from command-and-control to incentive-based policy instruments can be understood as a natural consequence of more ambitious environmental targets and/or cost-reducing technological progress. The different paths observed in the European democracies, [**Q**] to [**T**], and the U.S., [**Q**] to [**P**], can partly be understood as a result of the *interaction* between cross-country differences in political institutions and the time trends in environmental targets and abatement costs, and partly as a result of learning-by-doing effects in permit trading.

Our model is simplistic and can be extended in many directions. We conclude by discussing two of the most obvious extensions:

- **Endogenous emission targets**. We treat the emission target as an exogenous variable. While this is justified in many situations, as discussed in the introduction, ultimately environmental targets are decided upon by societies, and a complete theory of environmental policy would treat the two dimensions simultaneously. When the targets are decided in international negotiations, the political economy of these would have to be modeled to capture the feedback from instrument choice to environmental targets. Doing so is an ambitious undertaking which would be of considerable interest in future research. A more straightforward extension that can be dealt with within the framework of the current model is to allow the society to decide on the instrument and the target jointly. This would help us understand the simultaneous move towards stricter environmental targets and the use of more efficient policy instruments.

- **Policy packages**. Our model focuses on transitions between political equilibria in which a particular instrument is being used. In reality, environmental policy is simultaneously conducted by means of many different policy instruments. A complete theory would have to take this fact into account.

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