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Transitional politics: emerging incentive-based instruments in environmental regulation

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Abstract

This paper proposes a positive theory of environmental instrument choice. We study a democratic society that seeks to lower the level of pollution from industrial sources to a pre-specified target. The target can be implemented by one of three instruments: [**S**]: *uniform emission standards*; [**P**]: *tradeable permits*; and [**T**]: *emission taxes*. The conflict of interest between special-interests, representing polluters, and the electorate is resolved by an elected politician. We characterize when each of the three policy instruments is chosen in political equilibrium and show that the transition, observed in many countries, from [**S**] to either [**P**] or [**T**] can be understood as a natural consequence of increasingly ambitious environmental targets.

JEL classification: D78; H23; Q28

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1. Introduction

In the past two decades, the conduct of environmental policy to control air pollution and other environmental problems has changed in all major Western democracies. This is reflected not only by increasingly ambitious environmental targets but also in the instruments used to achieve these targets. Traditionally, environmental policy has been based on the so-called command-and-control instruments, such as design standards that require the use of a particular technology or performance standards or quotas that prescribe the maximum amount of emission allowable from each source. Although these tools are still widely used, a remarkable shift towards the use of

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incentive-based instruments, such as environmental taxes and tradeable pollution permits, has taken place in recent years. Many European countries, most notably perhaps the Scandinavian countries but also countries such as the United Kingdom, Germany and France, have introduced various environmental taxes to control emission of CO_2 and SO_2 [4,22]. Measured against GDP, the revenue generated by environmental taxes has increased from 2.1% to 2.9% between 1980 and 1997 in EU15 [11].[1] In the United States, markets for tradeable pollution permits have been established to help control SO_2 emissions and other air pollution problems with the Acid Rain Program implemented under Article IV of the Clean Air Act amendment of 1990 being the most famous and successful example [9,23]. The interest in establishing markets for tradeable pollution permits is also present in Europe where the Commission of the European Union, having failed to gain support for a common CO_2 tax in the early 1990s, is setting up a market for greenhouse gas emission permits starting from year 2005. In addition to this, one of the cornerstones of the so-called flexibility mechanism under the Kyoto Protocol (Article 17) is to develop an international market for CO_2 emission permits. The broad picture is fairly clear: the tendency is to move away from direct command-and-control regulation towards the use of green taxes and markets for tradeable pollution permits to combat air pollution (and other environmental) problems.

This paper proposes a positive theory of environmental instrument choice that can illuminate these tendencies. The theory is based on the notion that environmental policy choices in a representative democracy are the outcome of compromises between the conflicting interests of politicians, voters and lobby groups. Politicians value political office but are also responsive to special interests. Voters care about environmental damage and tax revenues as well as about the potential inefficiencies generated by the choice of policy instrument. They attempt to control the behavior of politicians by making re-election contingent on past behavior. An industry lobby group represents polluters in the political process. Its main objective is profit maximization and it seeks political influence by providing monetary rewards to politicians. We imagine a society that seeks to lower the level of pollution from industrial production to a pre-specified target and focus on the choice of the policy instrument used to implement the target. This makes sense when countries 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 national greenhouse gas reduction targets introduced by the United Kingdom and other European countries in the mid-1990s, see [20].

The pre-specified target can be implemented by one of three policy instruments: [**S**]: *uniform emission standards,* which cannot be tailored to firm-specific conditions; [**P**]: *tradeable permits*, which are allocated to firms free of charge; and [**T**]: *emission taxes*, where the revenue is (at least partly) recycled to the electorate. The three instruments are highly stylized but capture salient differences between actual policies.[2] First, because of unobserved firm heterogeneity, [**S**] cannot achieve the target at minimum abatement cost and so, [**T**] and [**P**] are superior from a cost

[1] In this calculation, "environmental taxes" are defined as "taxes with an environmental goal" and include as a major component energy and other product taxes.

[2] Other considerations include performance of the three alternatives in the face of uncertainty and incentives for innovation (see Kolstad and Toman [18] for a recent discussion of these issues in the context of climate policy).

effectiveness point of view. On the other hand, precisely because of heterogeneity, the uniform quota imposed under [**S**] may be binding only for some firms. When this is the case, aggregate output and total emissions are lower under [**S**] than under the two incentive-based instruments and the output price is higher. Second, [**T**] implies a net transfer from the industry to citizen-consumers (the electorate) which is not present under [**P**] where the industry is not exposed to the financial burden arising from taxation of unabated emission. Thus, the distinction between [**P**] and [**T**] is related to who gets the revenues: [**T**] gives the property right to the revenue to citizen-consumers, while [**P**] gives it to the industry. 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 the industry, then [**T**] would become like [**P**]. Likewise, if, as discussed by Grafton and Devlin [14], the government combines [**P**] with a charge that extracts (part of) the rent from the industry or if it auctions off the permits and recycles the revenue to citizen-consumers, then [**P**] becomes like [**T**]. Accordingly, the two policy instruments can be given different interpretations. However, to keep as closely as possible to the policy alternatives that have been used in practice, we shall throughout think of [**T**] as a tax instrument with recycling of revenues to citizen-consumers and [**P**] as a system of tradable permits under which the permits are allocated to the industry free of charge.

We characterize the instrument choice in political equilibrium in terms of economic and political fundamentals, in particular, the stringency of the environmental target. Our model can be seen as a generalization of the theory of environmental regulation pioneered by Buchanan and Tullock [3] in two directions: we expand the set of instruments by [**P**] and model, formally, the political conflict between industrial polluters and voters. More importantly, however, a static theory is not enough to understand the changes in instrument choices and we develop a dynamic theory that can explain the move from [**S**] to [**P**] or [**T**] when all agents correctly anticipate the future path of the economy, including future political equilibria.

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. For lax environmental targets, all parties—citizen-consumers as well as the lobby group representing the polluting industry—support [**S**]. The industry lobby supports [**S**] because of the price effect that increases total industry profits, and citizen-consumers support [**S**] because actual environmental damage is lower than with the other instruments. As the target becomes more stringent, a conflict of interest between citizen-consumers and the industry lobby emerges that has to be resolved by the elected politician. The industry lobby gradually becomes more interested in cost-efficiency and shifts its support to [**P**]. At the same time, the potential tax revenue available for recycling starts to increase and citizen-consumers shift their support to [**T**]. This eventually moves the economy away from [**S**] to either [**T**] or [**P**]. The precise transition pattern depends on political and economic fundamentals. We discuss in detail two possibilities that broadly correspond to the development in air pollution regulation observed during the 1980s and 1990s in Western Europe and the United States. The [**P**]-path represents a direct transition from [**S**] to [**P**] as observed in the United States. The [**T**]-path represents a direct transition from [**S**] to [**T**] as observed in many Western European countries. Access to a large product market makes the [**P**]-path a more likely outcome. The same is true when political institutions make it easy for special interests to gain political influence (e.g., by imposing few restrictions on campaign contributions) or reduce the cost of buying political influence by shortening the time horizon of politicians (e.g., by imposing term limits).

Accordingly, the different paths chosen in Western Europe and the United States can, at least partly, be attributed to differences in product market size and to differences in political institutions as captured by restrictions on campaign contributions and term limits.

The rest of the paper is organized as follows. In Section 2, we survey previous theoretical contributions to the literature on the political economy of instrument choice. In Section 3, we present the economic structure of our model. In Section 4, the nature and impact of the three policy instruments are set out and the policy preferences of the industry lobby (Proposition 1) and citizen-consumers (Proposition 2) are derived. In Section 5, we describe political decision making. In Section 6, we characterize political equilibrium (Proposition 3) and analyze the transition from one equilibrium to another as a function of the path of environmental targets (Proposition 4). In Section 7, we discuss the robustness of the main results. In Section 8, we conclude.

2. Positive theories of instrument choice

In this section, we offer a selective review of the theoretical literature on the political economy of (environmental) instrument choice and relate our theory to existing work.[3] The classical paper in the area is Buchanan and Tullock [3]. 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 increases profits. Taxes, on the other hand, reduce industry profits and may induce some firms to relocate 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" [3, 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 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, thereby explaining the emergence of tax instruments in political equilibrium. This formulation also goes beyond treating the government as a monolithic entity that maximizes a single objective function, as is the custom in models based on the political support function approach.[5] In our approach, the interaction between voters, politicians and lobby groups is explicitly modelled. In addition, Buchanan and Tullock compare **[S]** to **[T]**. Including **[P]** in the menu of options introduces an

[3] The relevant literature has recently been surveyed in greater detail by Oates and Portney [21]. An important empirical application of the theory is Joskow and Schmalensee [16] who analyze the political economy of the US Acid Rain Program. Keohane et al. [17] propose a comprehensive theoretical framework for thinking about the political economy of instrument choice using the analogy of a political market. Hahn [15] provides further discussion.

[4] Maloney and McCormick [19] analyze further the conditions under which a quota system can be profit-enhancing. Dewees [6] 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.

[5] See the discussion in Oates and Portney [21].

important, additional element, as previously noted by Dewees [6].[6] We show that the industry, in fact, prefers **[P]** to **[S]** when the environment target is sufficiently demanding.

Dijkstra [8, Chapters 8 and 9] analyzes 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 leads to the conclusion that tax instruments (**[T]**) are rarely chosen in political equilibrium. Dijkstra [7] 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 **[S]** despite the fact that **[T]** is available. They do not directly explain why we may observe a shift away from **[S]** to more efficient policy instruments, **[T]** or **[P]**. This question is addressed formally by Boyer and Laffont [2]. They formulate the problem as one of 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 that has private information about the cost of a polluting project. Due to asymmetric 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 (**[S]**) and a menu of pollution tax/transfer pairs (**[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 **[T]** for distributional reasons. Boyer and Laffont [2] show that **[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, $\{[\mathbf{S}], [\mathbf{P}], [\mathbf{T}]\}$, as given, and we do not consider the possibility of constitutional constraints. Instead, we evaluate when and whether each instrument is part of a *political equilibrium* for given institutional structures. 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.

3. The economy

Economic activity and policy choices take place over infinite discrete time, $t = 0, 1, 2, \ldots$. 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 emission of pollutants from industrial sources (firms) e_t. Utility is discounted at the rate β. The price of good

[6] He shows that industry interests could well prefer a system of tradable permits to command-and-control instruments if the permits are distributed for free.

x_t is denoted p_t and is determined in a competitive product market. Each citizen-consumer is endowed with K units of the numeraire good every period. The public good is, where applicable, financed by the revenue generated by an emission tax.[7] We assume that the instantaneous (indirect) utility function is

$$v(p_t, e_t) = K + \frac{1}{2}(a - p_t)^2 - D(e_t) + g_t, \quad a > 0, \tag{1}$$

where environmental damage is an increasing, convex function of total emissions

$$D(e_t) = \frac{1}{2}e_t^2 + be_t, \quad b > 0 \tag{2}$$

and demand for good x_t is $x_t^d = a - p_t$. The parameter a can be interpreted as a measure of product market size.

A continuum of firms, of measure 1, produce good x. The cost of producing x is different for firms with different types as captured by the productivity parameter θ_i. A firm with a low θ_i has low productivity (or high costs). For simplicity, we restrict attention to the two-type case and assume that half the firms have low productivity with $\theta_L = 1$ and that the other half have high productivity with $\theta_H > 1$.[8] Two characteristics of the distribution of types are important for the analysis, namely, the arithmetic mean, $\mu = \frac{1}{2}(1 + \theta_H)$, and the harmonic mean, $\eta = \frac{1}{E\frac{1}{\theta}} = \frac{2\theta_H}{1+\theta_H}$. By Jensen's inequality, it follows that $\eta < \mu$. The cost function of a firm of type θ_i $(i = L, H)$ is

$$c_i(x_{i,t}) = \frac{x_{i,t}^2}{2\theta_i}. \tag{3}$$

Production of x pollutes the environment. We assume that emissions from each firm are proportional to output:

$$e_{i,t} = x_{i,t}. \tag{4}$$

This implies that firms can reduce emissions only by reducing output.[9] In the absence of any environmental regulation, we note that firms of type θ_i would want to supply $x_{i,t} = \theta_i p_t$ units of output (and emission). Market clearing in the product market requires that demand, $a - p_t$, is equal to aggregate supply, μp_t, and so, the market clearing price is $\frac{a}{1+\mu}$. The unregulated level of emission from firms of type θ_i is $\frac{a\theta_i}{1+\mu}$ with total emission $\frac{a\mu}{1+\mu}$. Intuitively, in the absence of any regulation, firms with high productivity (low cost of production) find it optimal to produce and emit more than firms with low productivity (high costs of production). The government cannot observe θ_i for individual firms but knows the distribution of types. This implies that command-and-control regulation cannot be tailored appropriately to the conditions of each firm.

[7] 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. [13], this may underestimate the efficiency gains of **[T]**.

[8] These simplifying assumptions are not essential for the main results (see the discussion in Section 7).

[9] The specification rules out that investments in abatement effort can reduce emissions. This simplification is, however, not critical for the results that follow (see Section 7).

4. Environmental regulation

We consider a society that is committed to reduce emissions according to a pre-specified target, denoted $\bar{e}_t > 0$. The target $\bar{e}_t$ can be implemented by means of one of three policy instruments, **[S]**, **[P]**, or **[T]**, as discussed in Section 1. Under **[S]**, a *uniform* emission quota is issued to each firm that allows to emit up to $\bar{e}_t$ units per period. In this case, firms maximize profits

$$\pi_{t,i} = p_t x_{i,t} - \frac{x_{i,t}^2}{2\theta_i} \tag{5}$$

subject to $e_{i,t} \leqslant \bar{e}_t$. To avoid exceeding the quota some firms may have to scale down production. It is clear that the constraint is going to affect firms of type θ_H before it affects firms of type θ_L. Under **[P]**, the government issues, in total, permits corresponding to the environmental target, $\bar{e}_t$. These are distributed to the firms in the industry free of charge. The permits can be traded in a competitive permit market and are valid for one period only. In this case, firms maximize profits

$$\pi_{t,i} = p_t x_{i,t} - \frac{x_{i,t}^2}{2\theta_i} + q_t(\bar{e}_t - e_{i,t}), \tag{6}$$

where $q_t \geqslant 0$ is the permit price. A firm that wants to emit more that $\bar{e}_t$ units can do so provided it obtains additional permits from another firm that is willing to reduce its emission below $\bar{e}_t$. The third policy instrument, **[T]**, is an emission tax. Each firm is required to pay τ_t per unit of unabated emission. In this case, firms maximize profits

$$\pi_{t,i} = p_t x_{i,t} - \frac{x_{i,t}^2}{2\theta_i} - \tau_t e_{i,t}. \tag{7}$$

The tax rate is adjusted each period by the government to achieve the environmental target and the tax revenue, if any, is recycled to citizen-consumers (as public goods). Under all three instruments, the price of good x_t adjusts to clear the product market in each period.

Before analyzing the instrument choice in political equilibrium, we need to characterize the policy preferences of the industry and of citizen-consumers. Profit and utility levels under each policy regime depend critically on the stringency of the environmental target. Three critical values of the target, denoted e_L, e_H and e_u with $e_L < e_u < e_H$, are important for the analysis and are shown in Fig. 1.

Two of these, e_L and e_H, define the target levels at which the quota issued under **[S]** becomes binding for firms of type θ_L and θ_H, respectively, and are equal to[10]

$$e_L = \frac{a}{2} \tag{8}$$

[10] The threshold e_H is simply the level of emissions from a firm of type θ_H in the unregulated economy. To derive the threshold e_L, suppose that the constraint is binding for both types of firms. Then, aggregate supply is $\bar{e}_t$ and market clearing requires that $p_t = a - \bar{e}_t$. The optimal unregulated level of emissions from firms of type θ_L is equal to p_t. Thus, for targets below $e_L = \frac{a}{2}$, the target will be binding for firms of type θ_L, while for targets above this threshold (but below e_H), it will only bind for firms of type θ_H.

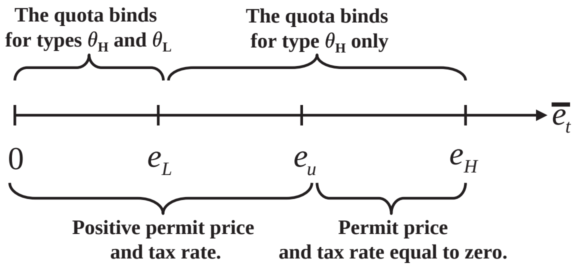

Fig. 1. The three critical values of the environmental target.

and

$$e_H = \frac{a\theta_H}{1+\mu}. \tag{9}$$

For targets below e_L, both types must reduce emission (and output) to meet their quota. Aggregate output (and total emission) is therefore $\bar{e}_t$ and the price that clears the product market is $a - \bar{e}_t$. Importantly, for $\bar{e}_t \in (e_L, e_H]$, only firms of type θ_H need to reduce emission to meet the quota; firms of type θ_L continue to emit and produce as in the absence of the quota. In this case, aggregate output (and total emission) is $\frac{a+\bar{e}_t}{3}$. Since $\frac{a+\bar{e}_t}{3}$ is less than $\bar{e}_t$, the equilibrium product market price, $\frac{2a-\bar{e}_t}{3}$, is larger than $a - \bar{e}_t$.

The third critical value, e_u, relates to whether permits are traded in the (competitive) permit market introduced under [**P**]. If the total number of permits issued by the government is larger than

$$e_u = \frac{a\mu}{1+\mu}, \tag{10}$$

then there is excess supply at $q_t = 0$. Thus, permits are only traded if $\bar{e}_t$ is less than e_u and the resulting equilibrium price in the permit market is $q_t = a\left(1 - \frac{\bar{e}_t}{e_u}\right)$. The price that clears the product market is $a - \bar{e}_t$. Trading guarantees that emission reductions are undertaken at minimum cost. The critical value, e_u, also denotes the environmental target at which $\tau_t = 0$ can implement the target. For $\bar{e}_t < e_u$, the government must impose an emission tax equal to $\tau_t = a\left(1 - \frac{\bar{e}_t}{e_u}\right)$ to reduce emissions to the target. Again, the equilibrium product market price is $a - \bar{e}_t$ and emission reductions are undertaken at minimum cost. For $\bar{e}_t > e_u$, we have $\tau_t = q_t = 0$ and outcomes under [**T**] and [**P**] are identical. That is, aggregate output and total emissions are $e_u < \bar{e}_t$ and the equilibrium product market price is $\frac{a}{1+\mu}$. This effectively corresponds to the unregulated equilibrium. Notice that for $\bar{e}_t \geqslant e_H$ and for $\bar{e}_t = 0$, the instrument choice is irrelevant and we, therefore, restrict attention to targets $\bar{e}_t \in (0, e_H)$.

Propositions 1 and 2 evaluate industry profits (denoted $\pi_t[I_t]$) and utility levels (denoted $u_t[I_t]$) under the three instruments $(I_t \in \{T, P, S\})$ as a function of the environmental target.[11]

[11] The relevant expressions are summarized in Table 1 in the Appendix.

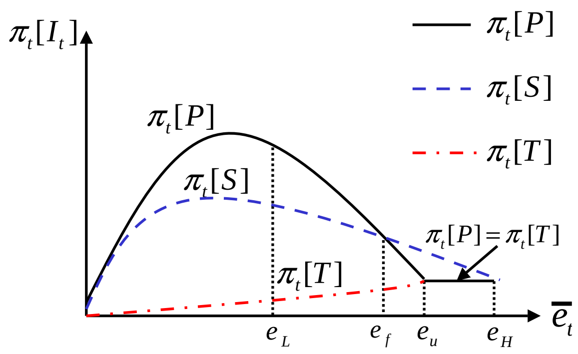

Fig. 2. Industry profits under [**S**], [**P**], and [**T**] as a function of the environmental target.

Proposition 1 (Industry profits). *There exists a target,* $e_f \in (e_L, e_u)$, *such that*

1. $\pi_t[P] \geqslant \max\{\pi_t[T], \pi_t[S]\}$ *whenever* $\bar{e}_t \in (0, e_f]$.
2. $\pi_t[S] > \max\{\pi_t[P], \pi_t[T]\}$ *whenever* $\bar{e}_t \in (e_f, e_H)$.

Proof. See the Appendix. □

The policy preference of the industry lobby is shown in Fig. 2 as a function of the target.[12] The industry lobby never (strictly) prefers [**T**] to [**P**]: the two instruments generate the same (least) cost allocation of emission reductions and the same product market price but under [**T**], the industry pays tax on unabated emissions. Under [**P**], no such financial burden is imposed on the industry.[13] The policy preference of the industry with regard to [**P**] and [**S**] is determined by two considerations. On the one hand, the industry would like emission reductions undertaken cost effectively. The flexibility to achieve this aim is allowed by [**P**] but not by [**S**]. On the other hand, the industry would like to increase profits. Under [**P**] trading implies that output is maximized subject to the environmental target. Output maximization does not imply profit maximization and the industry as a whole can increase profits by restricting output below the maximum allowed. This can be achieved by [**S**] as long as some firms (of type θ_L) are not using their quota fully (i.e., for $\bar{e}_t > e_L$). For lax environmental targets this effect is more important than the concern for cost effectiveness and for targets above the critical value e_f, industry profits are maximized by [**S**]. Once the target falls below e_f, the cost flexibility allowed by permit trading becomes the dominating force and industry profits are maximized by [**P**]. An implication, then, is that we should observe societies in which the government is captured by industry interests moving from [**S**] to [**P**] as environmental targets are gradually tightened but never to [**T**]. Hence, within the framework of our model, the Stigler–Peltzman theory of distributive politics predicts a two-stage transition: [**S**] to [**P**].

[12] It can be noted that none of the firms want to leave the industry as a result of environmental regulation. This is partly because of the price effect and partly because we do not consider fixed costs.

[13] For $\bar{e}_t \geqslant e_u$, [**P**] and [**T**] generate the same profits because $q_t = \tau_t = 0$.

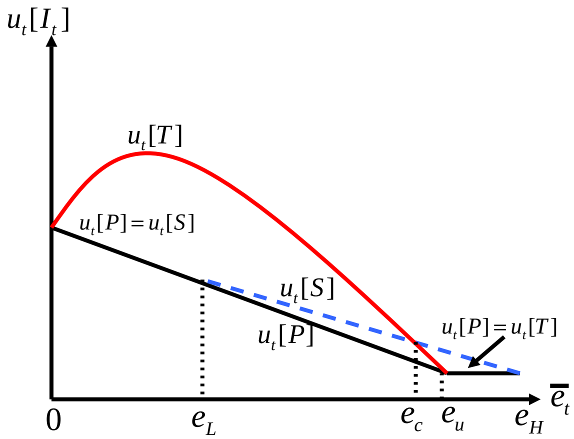

Fig. 3. Utility levels under the three policy instruments as a function of the environmental target.

Proposition 2 (Utility levels). *There exists a target,* $e_c \in (e_L, e_u)$ *with* $\frac{\partial e_c}{\partial b} < 0$, *such that*

1. $u_t[T] > u_t[S] \geqslant u_t[P]$ *whenever* $\bar{e}_t \in (0, e_c)$.
2. $u_t[S] \geqslant u_t[T] \geqslant u_t[P]$ *whenever* $\bar{e}_t \in [e_c, e_H)$.

Proof. See the Appendix. □

The policy preference of citizen-consumers is illustrated in Fig. 3. Citizen-consumers always find **[T]** at least as good as **[P]**: the two instruments generate the same consumer's surplus $\left(\frac{\bar{e}_t^2}{2}\right)$ and the same environmental damage $(D(\bar{e}_t))$ but **[T]** generates revenues, $T(\bar{e}_t) = a\left(1 - \frac{\bar{e}_t}{e_u}\right)\bar{e}_t$, for $\bar{e}_t < e_u$. Thus, their most-preferred policy is either **[S]** or **[T]**. When the target is lax $(\bar{e}_t \geqslant e_c)$, they prefer **[S]** to **[T]**. This is because tax revenues are modest (and for $\bar{e}_t \geqslant e_u$, in fact, zero) but environmental damage is lower under **[S]** than under **[T]**.[14] As the target becomes tighter, the opportunity cost of the foregone tax revenue increases and the difference in environmental damage under **[T]** and **[S]** decreases (and vanishes altogether for $\bar{e}_t \leqslant e_L$). As a consequence, once the target falls below e_c, citizen-consumers prefer **[T]** to **[S]**. An implication, then, is that in a "perfectly" functioning democracy where policy outcomes reflect sincerely the preferences of the electorate, we would expect to observe a transition from **[S]** to **[T]** as environmental targets become more strict but never to observe a transition to **[P]**. To understand actual policy choices in an "imperfect" democracy (where the politicians are responsive to the demands of special interests), it is important, as will become clear below, to notice that citizen-consumers have a strict second preference for **[S]** when $\bar{e}_t \in (e_L, e_c)$ because of lower emission levels under **[S]** than under **[P]**.

[14] The output price is higher under **[S]** than under **[T]** but for $b > 0$, the reduction in environmental damage dominates the loss in consumer's surplus.

5. The political model

We imagine that the instrument choice is an evolving compromise between the interests of politicians, voters, and special-interest groups. We model the political process as follows:

1. *Repeated elections and performance voting*. Voters delegate decision-making power to politicians in elections. We assume that citizen-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 Ferejohn [12], we assume that voters try to control politicians by setting performance standards. At the beginning of each period, they announce an election rule, $\eta_t(\cdot)$, which specifies whether $(\eta_t(\cdot) = 1)$ or not $(\eta_t(\cdot) = 0)$ the incumbent politician will be re-elected as a function of the policy instrument used to implement the target during the current term of office. If the incumbent is not re-elected, then he is replaced by an identical challenger. Let $I_t \in \{T, P, S\}$ be the policy choice in period t. We focus on the following type of election rule:
$$\eta(I_t) = \begin{cases} 1 & \text{if } I_t = I_t^*, \\ 0 & \text{otherwise,} \end{cases} \tag{11}$$
where $I_t^* \in \{T, P, S\}$ is the policy standard announced at the beginning of period t and I_t is the actual policy choice. That is, voters re-elect the incumbent politician if and only if he implements the environmental target using the policy instrument I_t^*. The performance standard is set each period to maximize life-time utility and applied retrospectively.
2. *Lobbying activities*. We assume that all firms in the industry join forces and organize a lobby group, despite the free rider problem. The industry lobby group represents the interests of all firms sincerely in the political process and is able to redistribute internally among the members.[15] We assume that the lobby group offers payments to the politician in return for specific policies as in Bernheim and Whinston [1]. These rewards are valued by the politician and one interpretation is that they represent campaign contributions 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, the lobby group offers a payment function, $b_t[I_t]$, that maps the policy choice made by the incumbent politician in a given period into a (non-negative) monetary payment. The lobby group discounts the future at rate β and its payoff is $\sum_{t=0}^{\infty} \beta^t(\pi_t[I_t] - b_t[I_t])$.
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, z, each period he holds office. We assume that z is

[15] We discuss briefly the case in which the two types of firms organize separate lobby groups in Section 7.

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

$$z + b_t[I_t]. \tag{12}$$

We assume that a politician that is voted out of office is never re-elected and gets 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 re-election rule. This is observed by all. Next, the lobby group announces a payment function to the politician. Taking as given the re-election rule and the payment function, the incumbent politician implements a policy, $I_t \in \{S, P, T\}$. The lobby group then makes the promised payment and a new election is held. This sequence of events repeats itself every period.

6. Political equilibrium

We define political equilibrium as a Markov perfect equilibrium (see, e.g., [5]). We shall analyze how the political equilibrium changes as the key exogenous variable of the model, $\bar{e}_t$, evolves over time. However, before we do so, we characterize the set of stationary political equilibria. To this end, assume that $\bar{e}_t = \bar{e}$ for all t. This makes the economy completely stationary and if something is an equilibrium in period t so it is in period $t + i$, $i = 1, \ldots, \infty$. To further aid the exposition but without loss of essential insights, we shall throughout assume that $e_c = e_f$.[16] The (stationary) equilibrium configurations of the game are summarized in Proposition 3.

Proposition 3 (Stationary policy choices). *Assume that* $e_c = e_f$. *Let* $Z = \frac{\beta z}{1-\beta}$ *and* $T(\bar{e}) = a\left(1 - \frac{\bar{e}}{e_u}\right)\bar{e}$. *The following stationary policy sequences constitute political equilibrium paths*:

1. $\hat{I} = \mathbf{S}$ *whenever either*
   (a) $\bar{e} \in [e_f, e_H)$; *or*
   (b) $\bar{e} \in (e_L, e_f)$ *and* $\pi[P] - \pi[S] < Z \leqslant T(\bar{e})$;
2. $\hat{I} = \mathbf{P}$ *whenever either*
   (a) $\bar{e} \in (0, e_L]$ *and* $T(\bar{e}) \geqslant Z$; *or*
   (b) $\bar{e} \in (e_L, e_f]$ *and* $\pi[P] - \pi[S] \geqslant Z$;
3. $\hat{I} = \mathbf{T}$ *otherwise*;

Proof. See the Appendix. □

Proposition 3 shows that each policy instrument is chosen in political equilibrium under appropriate conditions. For a sufficiently lax environmental target, $\bar{e} \geqslant e_f = e_c$, all parties support

[16] Note that e_f is independent of b, while e_c is strictly decreasing in b, equal to e_u for $b = 0$, and converges to e_L for $b \to \infty$ (see the proof of Proposition 2). Thus, there exists a value of b such that $e_f = e_c$.

[S]. The industry lobby supports [S] because it helps sustain high profits by increasing the price of output. Citizen-consumers support [S] because, in equilibrium, total emission is below the target. Accordingly, the incumbent politician implements this policy for sure. Uniform emission standards are supported by all.

For environmental targets sufficiently strict, $\bar{e} < e_f = e_c$, the industry lobby supports [**P**], while citizen-consumers would ideally like the politician to use [**T**] to implement the target but, short of that, [S] is strictly better than [**P**] for $\bar{e} \in (e_L, e_c)$. This conflict of interest must be resolved by the politician who can either implement the policy preferred by voters and get re-elected or accept the reward from the industry lobby and lose office. Clearly then, to get [**P**] implemented, the industry lobby must compensate the politician for the resulting loss of office and pay a reward at least equal to Z—the present value of political office. Thus, Z represents *the cost of buying political influence*. How much the industry lobby is in fact willing to pay depends on the environmental target but also, for a given target, on the policy supported by voters: it is willing to pay $T(\bar{e})$ to avoid [**T**] but only $\pi[P] - \pi[S]$ to avoid [S].

When the tax bill is sufficiently small relative to the cost of buying political influence $(T(\cdot) < Z)$, the industry lobby is not willing to pay the required compensation to the politician, and, in contrast to Buchanan and Tullock [3], its preference does not prevail: citizen-consumers are successful in implementing their most-preferred policy, [**T**]. Moreover, even when the industry lobby is more than willing to compensate the politician for the loss of office *if* he implements [**P**] rather than [**T**] (i.e., $T(\cdot) \geqslant Z$), special interests may still not prevail. In particular, for $\bar{e} \in (e_L, e_c)$ and for intermediate costs of buying political influence,[17] voters can, by acting strategically, ensure the implementation of [S] instead of [**P**]: while the industry lobby is willing to pay a lot to avoid [**T**], it is not willing to pay enough to avoid [S]. This is simply because the industry lobby is better off under [S] than under [**T**] and so, it is less eager to block the implementation of [S].[18] For targets below e_L, the industry lobby's preference for [**P**] does, however, prevail politically, provided that it is willing to pay Z to avoid being exposed to the emission tax.

The proposition shows how equilibrium policy depends on the environmental target. The target evolves over time and this induces shifts in equilibrium policy. To analyze such policy transitions formally, we need to identify perfect foresight equilibria of the political game, where voters, politicians and the industry lobby correctly anticipate the sequence of environmental targets and the resulting sequence of policy choices. We assume that the sequence of environmental targets is decreasing over time (i.e., $\bar{e}_{t+1} \leqslant \bar{e}_t$), due, for example, to new and more ambitious international commitments. The characterization of perfect foresight equilibrium paths is greatly facilitated by the fact that Z—the present value of political office—is stationary. This implies that the cost of buying political influence is the same in any period and independent of the particular sequence of targets. Equilibrium outcomes then depend only on contemporaneous variables. In Proposition 4, we focus on two particular transition paths that move societies away from [S] but stress that *all* equilibrium paths generated by stricter environmental targets imply a shift away from command-and-control to incentive-based instruments.

[17] Intermediate costs means that $\pi[P] - \pi[S] < Z < T(\bar{e})$.

[18] Note that $T(\bar{e}) > \pi[P] - \pi[S]$ for all $\bar{e} \in (0, e_f]$.

Proposition 4 (Policy transitions). *Assume* $e_c = e_f$. *Let* $Z = \frac{\beta z}{1-\beta}$ *and* $T(\bar{e}_t) = a\left(1 - \frac{\bar{e}_t}{e_u}\right)\bar{e}_t$. *Suppose that* $\bar{e}_0 > e_H$ *and that the environmental target is decreasing over time* ($\bar{e}_{t+1} \leqslant \bar{e}_t$, $t = 0, 1, \ldots$). Then

1. *the economy transits from* [**S**] *to* [**P**] *whenever* $Z \leqslant T(e_f)$;
2. *the economy transits from* [**S**] *to* [**T**] *whenever* $Z \geqslant T\left(\frac{e_u}{2}\right)$.

Moreover, $T(e_f)$ *and* $T\left(\frac{e_u}{2}\right)$ *are increasing in a and* $T\left(\frac{e_u}{2}\right) > T(e_f)$.

Proof. See the Appendix. □

In the early stages of a process of gradual abatement, [**S**] is unanimously endorsed by all parties, as discussed above. Eventually, however, the target reaches the threshold $e_c = e_f$ and the tax revenue available for recycling becomes large enough to make voters support [**T**] and the price effect small enough to make the industry lobby support [**P**]. Accordingly, the transition to incentive-based instruments can be understood as a natural consequence of stricter targets: the support for [**S**] is effectively eliminated.

This is, however, not sufficient to pin down the exact nature of the transition. Whether a society transits from [**S**] to [**T**] or [**P**] depends on the cost of buying political influence relative to the industry lobby's willingness to pay rewards to the politician. Proposition 4 identifies sufficient conditions for two particular transition paths to arise: the [**P**]-path that predicts a direct transition to the permit solution and the [**T**]-path that predicts a direct transition to the tax solution.[19] The [**P**]-path is followed by societies in which the cost of buying political influence is low relative to the willingness to pay rewards ($Z \leqslant T(e_f)$). The industry lobby is willing to pay more to avoid the emission tax when its members have access to a large product market $\left(\frac{\partial T(e_f)}{\partial a} > 0\right)$. This is because a larger market encourages more production and emission and a higher tax rate is required to reduce emissions to the target level. The [**P**]-path is also more likely in societies that impose few restrictions on campaign contributions, thereby making it relatively easy for special interests to buy influence. In contrast, the [**T**]-path is followed by societies in which the cost of buying political influence is high relative to the willingness to pay rewards $\left(Z \geqslant T\left(\frac{e_u}{2}\right)\right)$.[20] This implies that the [**T**]-path is more likely to obtain where the product market is small $\left(\frac{\partial T\left(\frac{e_u}{2}\right)}{\partial a} > 0\right)$ and it is hard or expensive for special interests to buy political influence.

Insofar as firms in Western Europe operate in smaller (domestic) markets than their US counterparts, this can help explain why the [**T**]-path has been followed in many Western European countries, while the [**P**]-path has been followed in the United States. The lack of term limits in some European democracies increases β (and thus Z) and is another factor that can help explain why more attention has been paid to the tax solution in Europe. By the same token, the important

[19] Along all equilibrium path with strictly decreasing targets, a transition to [**T**] is eventually predicted. This is due to the Laffer curve effect that reduces the tax revenue collected (and with it, the lobby group's willingness to pay to avoid [**T**]) when the target becomes extremely strict. If output has some value, it is, however, doubtful if any society would ever want to choose targets that are strict.

[20] Notice that $T(\frac{e_u}{2}) = \max_{\bar{e}} T(\bar{e})$ and that the peak of the Laffer curve at $\frac{e_u}{2}$ is below e_L.

role that campaign contributions play in the United States may help explain why the [**P**]-path has been followed there. Roughly then, the two paths identified by Proposition 4 correspond to the stylized development in air pollution regulation observed in Western Europe and the United States during the 1980s and the 1990s.

7. Discussion

Our basic model is based on a number of simplifying assumptions that aid the exposition. In this section, we discuss the robustness of our results and some straightforward extensions.

7.1. Abatement choices and firm heterogeneity

In our basic model, the two types of firms can only reduce emissions by scaling down production. In reality, there are many different types of firms and they can, typically, invest in abatement technologies that enable them to reduce emissions while keeping output constant. None of these simplifying assumptions are, however, essential for the results presented in Propositions 1–4. The results generalize to the case where there is a continuum of firm types (distributed according to some density function $f(\theta)$ with support on $[\theta_L, \theta_H]$) and where firms can reduce emission by means of abatement investments.

To illustrate some of these points, we briefly discuss a particular generalization. Suppose that emission from each firm is increasing in output as before but can be reduced if the firm invests in abatement effort, $\alpha_{i,t}$, i.e., $e_{i,t} = x_{i,t} - \alpha_{i,t}$. The cost of abatement is increasing and convex in effort: $\frac{\alpha_{i,t}^2}{2\theta_i}$. Assume further that there is a continuum of firms with measure 1 whose cost parameters are distributed uniformly on the interval from θ_L to θ_H. In Fig. 4, we show a simulation of the utility of citizen-consumers (measured on the right-hand scale) under [**T**], [**S**] and [**P**] and industry profits (measured on the left-hand scale) under [**P**] and [**S**], all as a function of the target.[21] It is clear that the pattern is exactly the same as in our basic model (compare Fig. 4 with Figs. 2 and 3). The industry lobby prefers [**P**] once the target falls below the threshold e_f' and, likewise, citizen-consumers prefer [**T**] to [**S**] for targets below the threshold e_c'. For sufficiently lax targets, all parties support [**S**]. It is thus straightforward to generalize Propositions 3 and 4. We shall not pursue this in detail here but note that what is really important for our results is the fact that some firms are not constrained by [**S**] in the early stages of a process of gradual abatement. This leads to higher prices to the benefit of the industry and reduces aggregate emission below the target to the benefit of citizen-consumers.

7.2. Conflict of interest within the industry

Above we assumed that all firms in the industry join the "industry" lobby group and that disagreement between firms of different types about the choice of policy instrument is dealt with

[21] The example is based on the following parameter values $a = 10$, $\theta_L = 1$, $\theta_H = 4$ and $K = 50$. The thresholds e_L' and e_u' are defined as above, and b is chosen to ensure that $e_c' = e_f'$, where e_c' and e_f' are the critical values where citizen-consumers and the industry lobby change preference from [**S**] to [**T**] and [**P**], respectively.

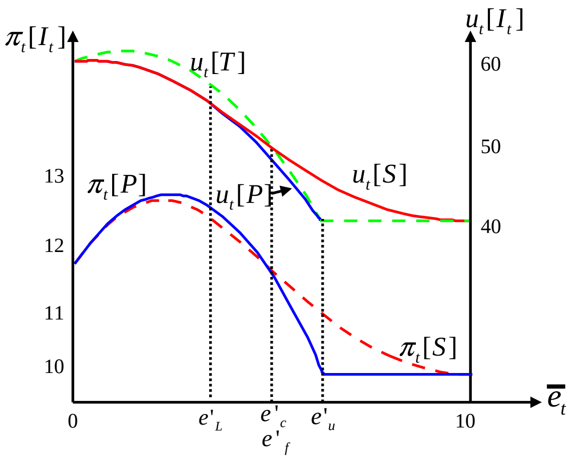

Fig. 4. Policy preferences with abatement choices and a continuum of firms.

internally, as is the distribution of the cost of lobbying. In reality, firms of different types may decide to organize separate lobby groups. To investigate this possibility, return to the two-type case and suppose that firms of different types organize two separate lobby groups, called lobby L and lobby H, respectively.

Fig. 5 shows the difference between the profit level under **[P]** and **[S]** for the two lobby groups as a function of the environmental target.[22] We notice that the two lobby groups are in agreement most of the time: for targets stricter than e_f^H, both lobby groups prefer **[P]** to **[S]** and for targets laxer than e_f^L both prefer **[S]** to **[P]**. However, for intermediate environmental targets ($\bar{e}_t \in (e_f^H, e_f^L)$), lobby L prefers **[P]**, while lobby H prefers **[S]**. The difference arises because redistribution takes place within the industry between sellers (firms of type θ_L) and buyers (firms of type θ_H) of permits. This conflict of interest between different segments of the industry makes it easier for voters to control the politician, either because lobby H joins forces with voters and is willing to support the politician for implementing **[S]** ($\bar{e} \in (e_f, e_f^L]$) or because the opposition to **[T]** is split between lobby H that supports **[S]** and lobby L that supports **[P]** ($\bar{e} \in (e_f^H, e_f)$).[23] In short, disagreement within the industry is likely to delay the introduction of incentive-based instruments and, once the transition happens, to make the **[T]**-path more likely than the **[P]**-path.

7.3. Reimbursement of tax revenues to polluters

Environmental tax programs in Europe and elsewhere range from programs where the tax revenue contributes almost entirely to the general public budget (as we assume above) to programs where the lion's share of the revenue is reimbursed to large industrial polluters and specific sectors are granted tax exemptions [10]. According to the classification made by Cansier

[22] An appendix with more details is available upon request.

[23] Here, we are assuming that $e_c = e_f$, where $e_f^H < e_f < e_f^L$.

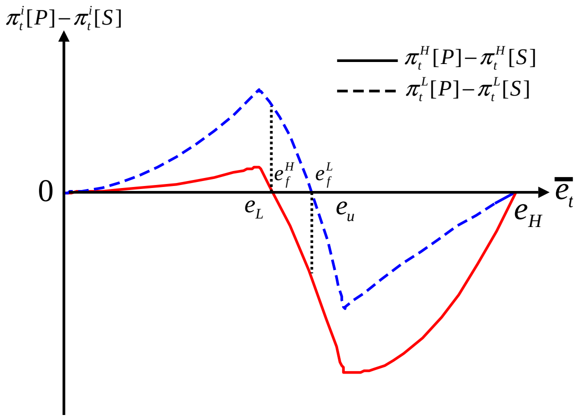

Fig. 5. The difference between profits under **[P]** and **[S]** for the two lobby groups.

and Krumm [4] for SO_2 and CO_2 taxes, the former approach is used in Sweden, Norway, the Netherlands and Finland, while versions of the latter approach is used in Denmark, France and Austria. This implies that actual tax policies in some cases are intermediate between **[P]** and **[T]**. Clearly, the industry lobby will block such an intermediate regime less often than the regime where voters get all the revenue.[24] This is simply because they are willing to pay less to see **[P]** rather than **[T]** implemented once the financial burden under **[T]** is reduced. The fact that reimbursement to industry and exemptions for heavy polluters are common practice in some European democracies has most likely reduced industry resistance and is undoubtedly one important factor in explaining the adoption of tax instruments across Europe [24].

8. 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 emission taxes and tradeable emission permits. The transition from command-and-control to incentive-based policy instruments can be understood as a natural consequence of more ambitious environmental targets.

Our model is simplistic but the main insights are robust to extensions in many directions, as discussed in the previous section. A more fundamental extension of interest for future research is to endogenize the environmental target. 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 and the model presented here can be seen as a useful stepping stone in that direction.

[24] By the same token, if some of the permits under **[P]** were sold in an auction to generate revenue to finance public services, the lobby group would be less willing to support **[P]**.

Acknowledgments

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Appendix

Table 1 summarizes the profit and utility levels under the three policy instruments as a function of the environmental target. The expressions can be found by substituting the price, output, and emission levels derived in the text into the profit and indirect utility functions, respectively. For mnemonic purposes, we label separately the two cases that can arise under each instrument (as shown in the Table's first column).

Proof of Proposition 1. First, note that $\pi_t[P] \geqslant \pi_t[T]$ for all $\bar{e}_t$. This is because **[P]** and **[T]** allow the industry to achieve the same least cost allocation of emission reductions and generate the same product market price but **[T]** may impose a financial burden on firms. For $\bar{e}_t \in (0, e_L]$, we get immediately from Table 1 that $\pi_t[P1] - \pi_t[S1] = \frac{\mu-\eta}{2\eta\mu}\bar{e}_t^2 > 0$. Consider a $\bar{e}_t \in (e_L, e_u]$, and define $\Delta\pi(\bar{e}_t) \equiv \pi_t[S2] - \pi_t[P1]$. Substitution from Table 1 yields

$$\Delta\pi(\bar{e}_t) = \frac{a^2}{9} - \frac{7a}{9}\bar{e}_t + \gamma\bar{e}_t^2, \tag{A.1}$$

where $\gamma \equiv \frac{58\theta_H + 31\theta_H^2 - 9}{36\theta_H(1+\theta_H)}$. This is a quadratic equation in $\bar{e}_t$, so it has at most two roots. Notice that (i) $\Delta\pi(0) > 0$, (ii) $\Delta\pi(e_L) = -\frac{\mu-\eta}{2\eta\mu}e_L^2 = -\frac{a^2(\theta_H-1)^2}{16\theta_H(1+\theta_H)} < 0$, and (iii) $\Delta\pi(e_u) = \frac{a^2(\theta_H+\theta_H^2+7\theta_H^3-9)}{27\theta_H(3+\theta_H)^2} > 0$ for $\theta_H > 1$. We conclude that $\Delta\pi(\bar{e}_t)$ has one and only one root in (e_L, e_u). Call it e_f. A simple calculation yields that

$$e_f = \frac{7 - \sqrt{49 - 36\gamma}}{2a}. \tag{A.2}$$

Moreover, $\Delta\pi(\bar{e}_t) \geqslant 0$ for $\bar{e}_t \in [e_f, e_u]$ and $\Delta\pi(\bar{e}_t) < 0$ for $\bar{e}_t \in (e_L, e_f)$. Finally, consider a $\bar{e}_t \in (e_u, e_H)$. Note that $e_f < e_u$; $\pi_t[P1] = \pi_t[P2]$ at e_u; $\pi_t[S2] - \pi_t[P2] = 0$ at e_H; and that $\pi_t[S2]$ is strictly decreasing in $\bar{e}_t$ for $\bar{e}_t \geqslant e_u$. Therefore, $\pi_t[S2] - \pi_t[P1] > 0$ at $e_u = \pi_t[S2] - \pi_t[P2] \geqslant 0$ for all $\bar{e}_t \in (e_u, e_H]$. □

Proof of Proposition 2. First, note that $u_t[T] \geqslant u_t[P]$ for all $\bar{e}_t$ because **[T]** and **[P]** generate the same environmental damage and the same p_t, but **[T]** might generate tax revenues. For $\bar{e}_t \in (0, e_L]$, **[S]**, **[P]** and **[T]** generate the same p_t and environmental damage but $\tau_t > 0$, so $u_t[T1] > u_t[S1] = u_t[P1]$. For $\bar{e}_t \in [e_u, e_H)$, $u_t[S2] - u_t[T2] = b\left(\frac{a\mu}{1+\mu} - \frac{a+\bar{e}_t}{3}\right) > 0$ and $u_t[T2] = u_t[P2]$. Consider, $\bar{e}_t \in (e_L, e_u)$.

Table 1
Industry profits and utility levels under the three policy instruments

Case	$\bar{e}_t$	π_t and u_t
[S1]	$(0, e_L]$	$\pi_t[S1] = (a - \bar{e}_t)\bar{e}_t - \frac{\bar{e}_t^2}{2\eta}$ $u_t[S1] = K - b\bar{e}_t$
[S2]	$(e_L, e_H]$	$\pi_t[S2] = \frac{a^2}{9} + \frac{2a\bar{e}_t}{9} - \frac{(9+5\theta_H)\bar{e}_t^2}{36\theta_H}$ $u_t[S2] = K - b\frac{a+\bar{e}_t}{3}$
[P1]	$(0, e_u)$	$\pi_t[P1] = (a - \bar{e}_t)\bar{e}_t - \frac{\bar{e}_t^2}{2\mu}$ $u_t[P1] = K - b\bar{e}_t$
[P2]	$[e_u, e_H]$	$\pi_t[P2] = \frac{e_u^2}{2\mu}$ $u_t[P2] = K - be_u$
[T1]	$(0, e_u)$	$\pi_t[T1] = \pi_t[P1] - a\left(1 - \frac{\bar{e}_t}{e_u}\right)\bar{e}_t$ $u_t[T1] = u_t[P1] + a\left(1 - \frac{\bar{e}_t}{e_u}\right)\bar{e}_t$
[T2]	$[e_u, e_H)$	$\pi_t[T2] = \frac{e_u^2}{2\mu}$ $u_t[T2] = K - be_u$

Define $\Delta u(\bar{e}) \equiv u_t[S2] - u_t[T1]$. Substitute from Table 1 to get

$$\Delta u(\bar{e}_t) = -\frac{ab}{3} + \left(\frac{2}{3}b - a\right)\bar{e}_t + \frac{3+\theta_H}{(1+\theta_H)}\bar{e}_t^2. \tag{A.3}$$

This is a quadratic equation, so it has at most two roots. Evaluate to see that (i) $\Delta u(-\infty) > 0$, (ii) $\Delta u(0) < 0$, (iii) $\Delta u(e_L) = -\frac{a^2(\theta_H - 1)}{4(1+\theta_H)} < 0$ and (iv) $\Delta u(e_u) = \frac{a(\theta_H - 1)b}{3(3+\theta_H)} > 0$. Hence, one root, call it e_c, belongs to $(e_L, e_u]$. We see that $\bar{e}_t \in (e_L, e_c] \Rightarrow \Delta u(\bar{e}_t) \geqslant 0$ and $\bar{e}_t \in (e_c, e_u) \Rightarrow \Delta u(\bar{e}_t) < 0$. Notice, moreover, that for $\bar{e}_t \in (e_L, e_H)$, $u_t[S] > u_t[P]$ because $u_t[S2] - u_t[P1] = b\left(\bar{e}_t - \frac{a+\bar{e}_t}{3}\right) > 0$ for $\bar{e}_t \in (e_L, e_u]$ and $u_t[S2] - u_t[P1] = b\left(e_u - \frac{a+\bar{e}_t}{3}\right) > 0$ for $\bar{e}_t \in (e_u, e_H)$. To prove that $\frac{\partial e_c}{\partial b} < 0$, note that $b = 0$ implies that $e_c = e_u$. Use the Implicit Function Theorem to calculate

$$\frac{\partial e_c}{\partial b} = -\frac{\frac{\partial \Delta u}{\partial b}}{\frac{\partial \Delta u}{\partial \bar{e}_t}}. \tag{A.4}$$

Note that $\frac{\partial \Delta u}{\partial b}\big|_{e_L} = 0$, that $\frac{\partial \Delta u}{\partial b \partial \bar{e}_t} > 0$, and that $\frac{\partial \Delta u}{\partial \bar{e}_t} > 0$ for $\bar{e}_t > e_L$. □

Proof of Proposition 3. For a given sequence of (stationary) re-election rules and reward functions, we can write the value function of the politician for an arbitrary policy implementation, I_t, as follows:

$$V[I_t] = b[I_t] + z + \eta(I_t)\beta \max V[I_{t+1}]. \tag{A.5}$$

Denote by $\hat{I}$ the policy choice made by the politician. The lobby group observes the re-election rule announced by the electorate and designs its reward function to maximize $\sum_{i=0}^{\infty}\beta^i(\pi_i[I_i] - b[I_i])$ anticipating that the politician chooses the policy that maximizes Eq. (A.5). Denote by $b^*[\cdot]$ the reward function offered by the lobby group. The politician observes each period the re-election rule and the reward function before he implements a policy. If he decides to comply and implement the policy demanded by voters, he gets

$$V_t^c = z + \beta \max\{V_{t+1}^c, V_{t+1}^d\}, \tag{A.6}$$

where V_t^d is what he would get if he decides instead to forego election and implement the policy that maximizes current rewards:

$$V_t^d = z + \max_{I_t} b^*[I_t]. \tag{A.7}$$

Note that $b^*[I^*] = 0$ because the lobby group is never willing to reward a policy that yields re-election of the politician. It is optimal for the politician to deviate from policy I^* if and only if $V_t^d > V_t^c$. Substitution yields

$$\max_{I_t} b^*[I_t] > \frac{\beta z}{1-\beta} \equiv Z. \tag{A.8}$$

Voters announce the re-election rule that maximizes discounted utility anticipating how the choice will affect the reward function offered by the lobby group and ultimately the actual policy choice, $\hat{I}$.

Policy outcomes depend on the target. We divided the analysis into three cases and assume that $e_c = e_f$. First, suppose that $\bar{e} \in [e_f, e_H)$. In this case, both voters and the lobby group support **[S]**, so this is surely the equilibrium outcome with $b[I] = 0$ for all I. Next, suppose that $\bar{e} \in (0, e_L]$. Notice that $u[T1] > u[P1] = u[S1]$. Accordingly, voters announce $I^* = T$ every period. Given this announcement, the industry lobby is willing to pay up to

$$\pi[P1] - \pi[T1] = T(\bar{e}) \tag{A.9}$$

to see **[P]** implemented instead of **[T]** and strictly less than that to see **[S]** implemented instead of **[T]**. The lobby group is not willing to pay in support of **[T]**. Hence, $b^*[P] = \min\{Z, T(\bar{e})\}$. If $T(\bar{e}) \geqslant Z$, the politician is willing to implement **[P]**; otherwise, $\hat{I} = T$. Finally, suppose that $\bar{e} \in (e_L, e_f)$. Recall that, in this case, $u[T1] > u[S2] > u[P1]$. Suppose that voters announce $I^* = T$. Then, if $T(\bar{e}) < Z$, **[T]** is, in fact, implemented ($\hat{I} = T$). However, if $T(\bar{e}) \geqslant Z$, $I^* = T \Rightarrow \hat{I} = P$. Since $u[S2] > u[P1]$ for $\bar{e} \in (e_L, e_f)$, voters would be better off if they could get **[S]** implemented instead **[P]**. Suppose, therefore, that they announce $I^* = S$. Now, **[S]** is implemented if

$$-\Delta\pi(\bar{e}) \equiv \pi[P1] - \pi[S2] < Z \tag{A.10}$$

where $\Delta\pi(\bar{e})$ is defined explicitly in the proof of Proposition 1. Recall that $\Delta\pi(e_f) = 0$; that $-\Delta\pi(e_L) = \frac{a^2(\theta_H - 1)^2}{16\theta_H(1+\theta_H)}$; and that $-\Delta\pi(\bar{e})$ is strictly decreasing for $\bar{e} \in (e_L, e_f)$. Moreover, $T(e_L) = \frac{a^2(\theta_H - 1)}{4(1+\theta_H)}$; $T(e_f) > 0$; and the peak of the Laffer curve is at $\frac{e_u}{2} < e_L$. We conclude that $-\Delta\pi(\bar{e}) < T(\bar{e})$ for $\bar{e} \in (e_L, e_f)$. To summarize: for $T(\bar{e}) < Z$, we have $I^* = T$, $b^*[P] < Z$, and $\hat{I} = T$; for $-\Delta\pi(\bar{e}) < Z < T(\bar{e})$, we have $I^* = S$, $b^*[P] < Z$, and $\hat{I} = S$; for $-\Delta\pi(\bar{e}) \geqslant Z$, we have $b^*[P] = Z$, and $\hat{I} = P$ for all I^*. □

Proof of Proposition 4. The politician can always obtain re-election by implementing the policy demanded by voters and the lobby group is never willing to reward a politician for implementing the policy that generates re-election. Thus, the politician can at most obtain a payoff equal to $Z = \frac{\beta z}{1-\beta}$ by doing what voters demand. This implies that for *any* sequence $\{\bar{e}_{t+i}\}_{i=0}^{\infty}$, the reward that the lobby group must pay in *any* period t to get the politician to implement something else than what voters want is Z. Add to these observations the fact that $\pi_t[I_t]$ and $u_t[I_t]$ are stationary functions of $\bar{e}_t$, then the stationary policy function, $I_t = \mathscr{I}(\bar{e}_t)$, that characterizes the instrument choice along any (perfect foresight) political equilibrium path can be deduced directly from Proposition 3. The two transition patterns highlighted in the proposition can be identified as follows. Recall that $T(\cdot)$ is maximized at $\frac{e_u}{2}$ and note that $T(\cdot) \geqslant \pi_t[P] - \pi_t[S]$ for all $\bar{e}_t < e_u$. Thus, for $Z \geqslant T\left(\frac{e_u}{2}\right)$, $\hat{I}_t = \mathbf{S}$ for $\bar{e}_t \in [e_f, e_H)$ and $\hat{I}_t = \mathbf{T}$ for $\bar{e}_t < e_f$. This proves case 1. Let $Z \leqslant T(e_f)$. Two sub-cases to consider. First, suppose $Z \geqslant \max\{\pi_t[P] - \pi_t[S]\} = \frac{\mu-\eta}{2\mu\eta} e_L^2$. Then $\hat{I}_t = \mathbf{S}$ for all $\bar{e}_t \geqslant e_L$, and the transition to **[P]** occurs when $\bar{e}_t$ falls below e_L. Second, let $Z < \frac{\mu-\eta}{2\mu\eta} e_L^2$. Then the transition to **[P]** occurs for a $\bar{e}_t$ larger than e_L. More specifically, denote the target level that solves $Z = -\Delta\pi(\bar{e}_t)$ for $\bar{e}_t > e_L$ by e_P, where $\Delta\pi(\bar{e}_t)$ is defined by Eq. (A.1). Then, for $\bar{e}_t > e_P$, $\hat{I}_t = \mathbf{S}$ and the transition to **[P]** occurs when $\bar{e}_t$ falls below $e_P > e_L$. This proves case 2. Notice that for targets lax enough, **[T]** is eventually adopted. This is because $T(\cdot)$ necessarily falls below Z when the tax rate becomes sufficiently large. Finally, write $T\left(\frac{e_u}{2}\right) = \frac{a^2\mu}{2(1+\mu)}$ which is increasing in a. Likewise, write $T(e_f) = e_f a - \frac{\mu e_f^2}{1+\mu}$. Substitute the expression for e_f from Eq. (A.2) to see that $\frac{\partial T(e_f)}{\partial a} > 0$. □

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