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Environmental Legislation and Enforcement: A Voting Model under Asymmetric Information*

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This paper examines the effects of asymmetric voter information on the environmental policies of democratic governments. The model builds on the electoral signaling model of Rogoff to illustrate the possibility that democratic governments may systematically overlegislate—and yet underenforce—environmental standards in a rational expectations equilibrium. The model also offers insights into the welfare implications of "right to know" legislation, proposals to depoliticize environmental policy, and private voluntary institutions.

This paper examines the effects of asymmetric voter information on the environmental policies of democratic governments. When free markets fail due to pollution externalities, government intervention offers the promise of Pareto improvement (Bator [2]). However, one cannot assume a priori that governments will always use their regulatory powers optimally. For instance, the rent-seeking literature suggests that if industry is better organized than the general citizenry, then the government may exhibit a bias against the environment and in favor of industry (e.g., Buchanan and Tullock [4], or, more recently, Hahn [7]). Indeed, the government may not even strike the proper balance between consumption and environmental quality in its *own* production—perhaps due to bureaucratic motives similar to those addressed by Niskanen [11] (e.g., Oates and Strassman [12] or Lyon [9]), or perhaps due to the government's imperfect information, as argued by Hayek [8] (see also Anderson and Leal [1]).

This paper builds on Rogoff [14] to identify yet another possible source of governmental failure—that associated with a temporary information asymmetry between voters and elected officials. In his paper, Rogoff analyzes political budget cycles and elections in the presence of asymmetric information (see also Milgrom and Roberts [10] and Terrones [15]). Rent-seeking incumbents in the Rogoff model exhibit a bias toward provision of easily monitored government expenditures on publicly provided consumption goods over more hard-to-measure public sector investments, choosing too little investment in an effort to signal competency and thereby gain reelection. The result, on average, is too little public investment.

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This paper extends the Rogoff analysis to the case of environmental regulatory policy. Government regulatory controls involve costs that reduce private consumption even as they increase the stock of environmental quality in the economy. Unfortunately, the degree to which this process can be controlled by voters is probably limited. In this paper we examine two potential biases. First, we consider the case in which the costs of environmental legislation are not observed until some future period when consumption is observed to fall. Incumbents have an incentive to exploit this information asymmetry. In particular, if incumbents vary with respect to their "competency," then higher competency incumbents may try to signal this to voters by implementing tough abatement legislation. In a separating equilibrium under asymmetric information, the result, on average, is a bias in favor of environmental quality.

Second, we consider the case in which incumbents have discretion over the enforcement of existing statutes. If incumbents have discretion over enforcement, and if incumbents' "regulatory zeal" is not observed by voters, there may also be a bias in the opposite direction; that is, incumbents may try to exploit this information asymmetry to signal their competency, shirking on enforcement in order to increase private consumption, which is more readily observed by voters. In a separating equilibrium under asymmetric information, the result, on average, is a bias against environmental quality.

The objective of this modeling exercise is to offer insights into both the environmental performance of existing institutions and the possible alternatives. In particular, the model offers insights into the welfare implications of public "right to know" legislation, proposals to depoliticize the environmental regulatory process, and private voluntary institutions.

I. THE MODEL

This section presents a highly simplified model of an economy with two goods: a private consumption good, x, and environmental quality, e. The private good is produced by a competitive industry, which faces pollution standards that are enacted and enforced by a single elected official, the "incumbent." Incumbents face reelection at the end of each period.[1] For analytical simplicity, the analysis focuses on the two-period case in which the incumbent faces an election in the first period to determine who will be in office in the second period.[2]

I.A. Citizen Preferences

There are assumed to be N individuals in the economy, $N - 1$ of whom work in the private sector and 1 of whom is the incumbent. For simplicity, all individuals in the private sector have preferences in each period given by $U_t = U(x_t, e_t)$, where $U(\ )$ is assumed to be strictly increasing and concave in its arguments. Given the

[1]The analysis departs in this respect from Rogoff [14], in which elections occur every other period. A single-period electoral structure simplifies the analysis and appears reasonable given that intraterm policy changes and intraterm competency variation—along with the *cycles* they can generate—are of secondary importance to the issues we address. Nevertheless, the analysis can be readily extended to the case of multiperiod terms.

[2]Although adding more periods is tedious, similar results are obtained.

voter's imperfect information about environmental quality, the voter's expected discounted utility in period 1 is

$$E[\Gamma_1] \equiv E[U(x_1, e_1) + \beta U(x_2, e_2)], \tag{1}$$

where β is the discount factor and E is the mathematical expectation, conditional on the voter's information set (see below).

I.B. Private Industry and Competitive Equilibrium

There is assumed to be a competitive, constant returns to scale industry that produces a nonstorable consumption good. Labor is the only factor of production in the economy, and it is supplied inelastically by the $N - 1$ laborers. Let the output per worker be a constant, ϕ. Then, in equilibrium, all $N - 1$ laborers will be employed, so that the (gross) output of private industry in period t is a constant, $Y \equiv \phi(N - 1)$.

Private production is assumed to generate raw pollution emissions, which can be abated with a known technology. However, as long as the environmental impact of any one firm in the competitive industry is relatively small, managers of profit-maximizing firms will minimize abatement expenditures—the classic externality problem. Thus, firms are assumed to set abatement, a_t, equal to a minimum level, $\bar{a}_t$, specified by the incumbent. The aggregate cost of abatement, C_t, includes both the expenses incurred by firms to comply with government regulations and the government's regulatory costs,

$$C_t = c\bar{a}_t - \varepsilon_t \qquad (\bar{a}_t \geq 0), \tag{2}$$

where c is the unit cost of abatement (assumed constant) and ε_t reflects the incumbent's efficiency or competency in time t (see below).

For simplicity, let the number of firms equal one.[3] The firm's profit equals the value of output minus (i) labor costs, $w_t(N - 1)$; (ii) the firm's abatement costs; and (iii) a lump-sum tax set to cover any government regulatory costs plus a market wage, w_t, paid to the incumbent. Normalizing the price of output, after-tax profits are

$$\pi_t = [y - w_t]N - c\bar{a}_t + \varepsilon_t, \tag{3}$$

where $y = \phi(N - 1)/N$ is gross output per capita in equilibrium. Assuming there are zero profits in competitive equilibrium, and all wages are consumed in the current period, we have[4]

$$\begin{aligned} x_t &= w_t \\ &= y - \frac{(c\bar{a}_t - \varepsilon_t)}{N} \qquad (x_t \geq 0). \end{aligned} \tag{4}$$

[3]One can easily introduce a large number of identical firms without affecting any of the results below.

[4]Note that x_t is bounded by $y + \varepsilon_t/N \geq x_t \geq 0$.

Intuitively, given the incumbent's level of efficiency and the cost of abatement, consumption is uniquely determined by $\bar{a}_t$, the government's regulatory policy.

I.C. Environmental Quality

Environmental quality evolves according to the motion equation

$$e_t = e_{t-1} + r - p_t, \tag{5}$$

where p_t is pollution at time t and r reflects the natural regenerative properties of the environment.[5] For simplicity, pollution in period t depends linearly on the level of output and the level of abatement,

$$p_t = \gamma Y_t - \bar{a}_t, \tag{6}$$

where γ is the "gross emissions" parameter. Thus, environmental quality can be written as

$$\begin{aligned} e_t &= e_{t-1} + r - \gamma y N + \bar{a}_t \\ &\left(= e_0 + t(r - \gamma y N) + \sum_{\tau=1}^{t} \bar{a}_\tau \right) \end{aligned} \tag{7}$$

so that environmental quality reflects current and past regulatory enforcement.

I.D. Incumbent's Problem

Following Rogoff, the incumbent derives a fixed rent, Z, from being in office, so that the incumbent's expected utility prior to the election in period 1 is

$$E^1(\Gamma_1) + Z + \beta E^1[\theta]Z, \tag{8}$$

where Γ is defined in (1) above, E^1 denotes expectations based on the incumbent's information set, and θ takes a value of one if the incumbent is reelected and zero otherwise.[6] Thus, any action taken by the incumbent must balance his/her interests concerning reelection with his/her interests concerning consumption and environmental quality in the current and future periods.

All individuals are identical up to an unobserved parameter, ε_t, that can be thought of as the individual's "competency." For instance, individuals might differ in their administrative skill or their regulatory policies.[7] Following Rogoff, the competency of a given agent is assumed to evolve according to the moving average

[5]The inclusion of a state variable mathematically distinguishes this model from those presented in the papers by Rogoff [14] and Terrones [15].

[6]Note that Z is a nonpecuniary benefit, although one might easily consider alternative formulations.

[7]More generally, one might interpret ε_t as the government's competency with respect to any hard to monitor policy that shifts the economy's production possibility frontier.

stochastic process

$$\varepsilon_t = \alpha_{t-1} + \alpha_t, \tag{9}$$

where each α is an independent drawing from a Bernouilli distribution with $\rho \equiv \text{Prob}(\alpha = \alpha^H)$ and $1 - \rho \equiv \text{Prob}(\alpha = \alpha^L)$, $\alpha^H > \alpha^L$, and α_0 given. The α shocks are independent across agents as well as across time. Competency may vary across time, both because external circumstances evolve, requiring different skills, and because there may be turnover among the leader's advisors.

In the following sections we consider two different scenarios concerning environmental policy formation. The crucial distinction between these two cases involves the degree to which environmental standards legislated in a given period can be evaded by incumbents attempting to weaken the implementation of such standards in the subsequent period. In the first case, the environmental policy in any period is assumed to be completely determined by past legislation, so that the incumbent's only task is to design legislation that will determine environmental policy in the subsequent period. In the second case, the incumbent has complete discretion over the enforcement of existing standards. In each case, the equilibrium allocation of resources will depend on the voter's information prior to the election. In the next section, we show that if legislated standards are binding, and if legislated standards are more readily observed than the costs of such standards, then the standards enacted will be too strict. In Section III, we show that if incumbents have discretion over enforcement, and if enforcement is relative difficult to observe, then incumbents will choose too little enforcement. These two scenarios are polar cases. However, we believe that they help to illuminate several chronic problems with environmental policy formation.

II. EQUILIBRIUM WITH BINDING LEGISLATION

We begin by assuming that the incumbent is constrained in any given period by the environmental legislation enacted in the previous period. That is, we assume $\bar{a}_t$ is legislated in $t - 1$ (with legislation in each period being enacted prior to the election in that period). Starting in $t = 2$, consumption is simply

$$x_2^* = y - \frac{(c\bar{a}_2 - \varepsilon_2)}{N}. \tag{10}$$

Thus, second-period utility for the representative voter is a function of (i) the inherited stock of environmental quality, $e_1 + r$; (ii) the abatement standards set in period 1; and (iii) the incumbent's competency in period 2. First-period environmental quality is simply a function of e_0 and $\bar{a}_1$:

$$e_1(e_0, \bar{a}_1) = e_0 + r - \gamma y N + \bar{a}_1. \tag{11}$$

Since both e_0 and $\bar{a}_1$ are determined prior to the start of the analysis, the voter's indirect second-period utility can be written as a function of $\bar{a}_2$ and ε_2:

$$V_2(\bar{a}_2, \varepsilon_2) = U(y - (c\bar{a}_2 - \varepsilon_2)/N, e_1 + r - \gamma y N + \bar{a}_2) \tag{12}$$

(where we suppress the exogenous arguments of $V_2(\ )$ for notational simplicity).

Furthermore, note that first-period consumption is determined by (i) the competency of the incumbent at the start of the analysis and (ii) the standards set prior to period 1:

$$x_1^* = y - \frac{(c\bar{a}_1 - \varepsilon_1)}{N}. \tag{13}$$

Thus, first-period utility is entirely exogenous: $U_1 = U(x_1^*, e_1(e_0, \bar{a}_1))$.

Finally, it is useful to define the representative voter's expected utility from reelecting an incumbent with a first-period competency shock α_1 to be

$$\Omega(\bar{a}_2, \alpha_1) \equiv \rho V_2(\bar{a}_2, \alpha_1 + \alpha^{\mathrm{H}}) + (1 - \rho)V_2(\bar{a}_2, \alpha_1 + \alpha^{\mathrm{L}}). \tag{14}$$

Because the incumbent's electoral opponent is chosen at random from the population, we have

$$\Omega^{\mathrm{O}} = \rho\Omega(\bar{a}_2, \alpha^{\mathrm{H}}) + (1 - \rho)\Omega(\bar{a}_2, \alpha^{\mathrm{L}}) \tag{15}$$

so that $\Omega(\bar{a}_2, \alpha^{\mathrm{H}}) > \Omega^{\mathrm{O}}(\bar{a}_2) > \Omega(\bar{a}_2, \alpha^{\mathrm{L}})$ for all $\bar{a}_2$.

Given these intermediate results, note that there is effectively only one decision facing the first-period incumbent: the choice of abatement standards that will be in force in period 2. In making this decision, the incumbent must balance his/her concerns over reelection against his/her private concerns over future consumption and environmental quality. In particular, the incumbent's optimal environmental strategy will depend on whether (i) voters are fully informed, or (ii) the incumbent must distort his/her environmental strategy to signal competency.

II.A. Full Information

Consider the benchmark case in which fully informed voters observe all period 1 variables prior to voting (including the incumbent's, but not the opponent's, competency). In this case, low-competency incumbents are voted out of office and high-competency incumbents are returned to office, *regardless* of the legislation they enact. This is because once $\bar{a}_2$ is determined, V_2 only depends on the competency of the government in that period (see Eq. (12) above).

Because the electoral outcome is unaffected by legislation enacted, the first-period choice facing the type H incumbent is

$$\max_{\bar{a}_2} \Omega(\bar{a}_2, \alpha^{\mathrm{H}}). \tag{16}$$

This is the same as the representative voter's problem given a type H incumbent, so that the incumbent's choice, denoted $\bar{a}_2^{\mathrm{HH}*}$, is efficient under full information.[8]

In contrast, the type L incumbent, knowing he/she will lose the election, solves the problem

$$\max_{\bar{a}_2} \Omega^{\mathrm{O}}(\bar{a}_2). \tag{17}$$

[8]The resulting first-order conditions are the well-known Samuelsonian conditions.

Again, this is the same as the voter's problem given a type L incumbent, so that the type L incumbent's choice, denoted $\bar{a}_t^{LO*}$, is efficient as well.

This completes the two-period analysis of the full information case. The next subsection considers the case in which the incumbent's competency is unobserved.

II.B. Asymmetric Information

In this section, we assume that while voters are able to observe current consumption and current and future government abatement standards, they are not directly able to observe the incumbent's competency prior to voting. In addition, we assume that voters do not know unit abatement costs.[9] In contrast, the incumbent is assumed to have full information (although not even the incumbent observes the opponent's type).

Given this information asymmetry, rational voters will nonetheless attempt to use all available information to form inferences about the leader's competency. Indeed, in this simple model it is likely that rational voters will be able to infer the differences between type H and type L incumbents in equilibrium, because (in a separating equilibrium) type H incumbents will be willing to enact tougher environmental statutes than type L incumbents, thereby *signaling* their higher competency and gaining reelection.

Throughout this section, we restrict attention to separating equilibria.[10] Following Rogoff, in a *sequential* equilibrium, voters select the candidate who maximizes their expected welfare given their beliefs, and the incumbent enacts environmental statutes to maximize his/her expected welfare. Let $\hat{\rho} = \hat{\rho}(\bar{a}_2)$ be the voter's inference concerning the probability that the incumbent is a type H incumbent given the observed environmental legislation.[11]

Separating Equilibrium

We define a separating equilibrium in this case to be one in which $\bar{a}_2^L \neq \bar{a}_2^H$. Clearly, in a separating equilibrium, the type L incumbent will employ his/her full information strategy, knowing he/she will not benefit from doing otherwise. Thus, we have

$$\bar{a}_2^L = \bar{a}_2^{LO*}. \tag{18}$$

To obtain the type H incumbent's equilibrium strategy, let A be the set of statutes that it would not benefit the type L incumbent to choose, even if he/she were to

[9]This additional assumption serves to rule out the possibility that voters might calculate competency given abatement and consumption. We believe this is a reasonable assumption insofar as voters are unlikely to have the same access that incumbents do to accurate cost estimates for the environmental legislation in question.

[10]We do not examine pooling equilibria in order to shorten and focus the analysis. For a formal treatment of pooling equilibria, see Rogoff's analysis.

[11]We assume that $\hat{\rho}$ is *Bayes consistent* in that if the incumbent's asymmetric information choices satisfy $\bar{a}_2^L \neq \bar{a}_2^H$, then $\hat{\rho}(\bar{a}_2^L) = 0$ and $\hat{\rho}(\bar{a}_2^H) = 1$. Thus, the incumbent assesses his/her chances of being reelected to be $\theta = \theta(\hat{\rho})$, where $\theta(1) = 1$ and $\theta(0) = 0$.

secure reelection by doing so:

$$A \equiv \{\bar{a}_2 | \Omega(\bar{a}_2, \alpha^L) + Z \leq \Omega^O(\bar{a}_2^{LO*})\}. \tag{19}$$

Define B to be the environmental statutes that it would benefit the type H incumbent to choose, if by doing so he/she is able to secure reelection,

$$B \equiv \{\bar{a}_2 | \Omega(\bar{a}_2, \alpha^H) + Z \geq \Omega^O(\bar{a}_2^{HO*})\}, \tag{20}$$

where $\bar{a}_2^{HO*} \equiv \underset{\bar{a}_2}{\text{argmax}}\ \Omega^O(\bar{a}_2)$.

So long as A is nonempty, the intersection of A and B contains those points that the type H incumbent might select in order to distinguish himself/herself from the type L incumbent:

PROPOSITION 1. *The set of all separating equilibria is nonempty and is characterized by* $\bar{a}_2^L = \bar{a}_2^{LO*}$ *and* $\bar{a}_2^H \in A \cap B$.

Proof. See Appendix A.

Following Rogoff, we can reduce the range of separating equilibria to a unique *undominated* separating equilibrium by assuming that voters are sophisticated enough that they will reelect the incumbent with probability one if $\bar{a}_2 \in S$ and elect the opponent otherwise. Let $\tilde{a}$ be the upper bound of the open set A' (where A' is the complement of A). We have the following proposition:

PROPOSITION 2. *There is a unique undominated separating equilibrium characterized by* $\bar{a}_2^L = \bar{a}_2^{LO*}$ *and* $\bar{a}_2^H = \max\{\tilde{a}, \bar{a}_2^{HH*}\}$.

Proof. See Appendix B.

Intuitively, the type L incumbent knows that it is not in his/her interest to mimic the type H incumbent if the type H incumbent chooses $\bar{a}_2 \in A \cap B$. However, the type H incumbent *will* set $\bar{a}_2 \in A \cap B$, since by doing so he/she will win the election, obtaining a level of utility that is greater than that if the opponent wins the election. Indeed, since the type H incumbent will win the election for all $\bar{a}_2 \in A \cap B$, the incumbent will choose his/her most preferred element of this set. However, as long as Z is large enough, type H incumbents will not be able to distinguish themselves without departing from their full information strategy. In this sense, asymmetric information will, on average, result in an inefficiently high level of environmental quality.[12]

III. EQUILIBRIUM WITH DISCRETIONARY ENFORCEMENT

In many cases it is reasonable to assume that legislation is not rigidly binding, but instead the incumbent has discretion over the enforcement of abatement standards. In this section we examine the polar case in which incumbent discretion

[12] Extension of the analysis to more periods is straightforward, albeit tedious. Complicating the analysis is the possibility that reelection in earlier periods can result in multiple additional terms in office, while environmental decisions in any period also affect all future periods. Nevertheless, the same basic principles continue to apply.

is complete, so that legislated abatement standards are irrelevant. The problem facing the incumbent prior to the election is not what statutes to enact for the future, but rather what abatement regulations to impose in the present. We show that if voters are fully informed about the incumbent's competence, then the voting equilibrium continues to be efficient. However, if the incumbent's competency is unobserved, the incumbent may attempt to manipulate current environmental policy so as to signal competency.

III.A. Full Information

We begin with the benchmark case of full information. Starting in the second period, incumbents of either type are no longer concerned with reelection. Thus, the incumbent's problem is simply to choose a level of abatement so as to maximize second-period utility. Casting the incumbent's problem in terms of choosing a level of consumption, we have[13]

$$\max_{x_2} U\left[x_2, e_1 + r - \gamma yN + \left(N(y - x_2) + \varepsilon_2\right)/c\right]. \tag{21}$$

Because the incumbent's problem is equivalent to the representative voter's problem, the incumbent will choose an efficient allocation of resources in the second period.

Define x_2^{j*} to be the second-period consumption choice of the type j incumbent. Comparative statics and the implicit function theorem yield

$$x_2^{j*} = x_2^*\left(e_1, \varepsilon_2^j\right) \qquad \text{with } \partial x_2^{j*}/\partial e_1 > 0 \text{ and } \partial x_2^*/\partial \varepsilon_2^j > 0, \tag{22}$$

where $\varepsilon_2^j \equiv \alpha_1 + \alpha_2^j$ for $j = \mathrm{L}, \mathrm{H}$. Redefining the relevant indirect functions, we have

$$V_2\left(e_1, \varepsilon_2^j\right) \equiv U\left[x_2^{j*}, e_1 + r - \gamma yN + \left(N\left(y - x_2^{j*}\right) + \varepsilon_2^j\right)/c\right] \tag{23}$$

and

$$e_1(x_1, \varepsilon_1) \equiv e_0 + r - \gamma yN + \left(N(y - x_1) + \varepsilon_1\right)/c, \tag{24}$$

where exogenous arguments are suppressed for simplicity.

Given these definitions, the voter's expected utility from reelecting an incumbent with period 1 competency shock of α_1 is

$$\begin{aligned}\Omega(e_1, \alpha_1) \equiv{}& \rho V_2\left(e_1, \alpha_1 + \alpha^{\mathrm{H}}\right) \\ &+ (1 - \rho) V_2\left(e_1, \alpha_1 + \alpha^{\mathrm{L}}\right).\end{aligned} \tag{25}$$

Because the opponent is drawn randomly from the population, the voter's expected utility from electing the opponent is redefined as

$$\Omega^{\mathrm{O}}(e_1) \equiv \rho\Omega\left(e_1, \alpha^{\mathrm{H}}\right) + (1 - \rho)\Omega\left(e_1, \alpha^{\mathrm{L}}\right). \tag{26}$$

[13]Choosing consumption is equivalent to choosing abatement, given Eq. (4).

Again, we have $\Omega(e_1, \alpha^H) > \Omega^O(e_1) > \Omega(e_1, \alpha^L)$ for all e_1, so that type H incumbents will be reelected and type L incumbents will not be reelected under full information.

To see the implications of these electoral outcomes for the incumbent's first-period decision making, it is useful to define the voter's expected utility if (i) the incumbent is reelected,

$$R(x_1, \alpha_1) \equiv V_1(x_1, \alpha_0 + \alpha_1) + \beta\Omega e_1(x_1, \alpha_0 + \alpha_1), \tag{27}$$

or (ii) if the incumbent is defeated

$$D(x_1, \alpha_1) \equiv V_1(x_1, \alpha_0 + \alpha_1) + \beta\Omega^O e_1(x_1, \alpha_0 + \alpha_1), \tag{28}$$

where

$$V_1(x_1, \alpha_0 + \alpha_1) \equiv U(x_1, e_1(x_1, \alpha_0 + \alpha_1)). \tag{29}$$

Given these definitions, the problem facing a type H incumbent in the first period is[14]

$$\max_{x_1} R(x_1, \alpha^H). \tag{30}$$

This is the same as the representative voter's problem (given a type H incumbent), so that the type H incumbent's first-period consumption choice, denoted x_1^{HI*}, is efficient. In contrast, the type L incumbent's first-period problem is

$$\max_{x_1} D(x_1, \alpha^L). \tag{31}$$

Again, this is the same as the voter's problem (given a type L incumbent), so that the type L incumbent's choice, x_1^{LO*}, is efficient.

This completes the two-period analysis of the full information case. Intuitively, incumbents will be reelected if and only if they have high competency shocks in the period of the election, so that there is no political advantage in pursuing inefficient levels of enforcement (indeed, there is a *private* incentive *for* efficient enforcement).

III.B. Asymmetric Information

In this subsection, we assume that while voters are able to observe current consumption (and perhaps the unit cost of abatement), they are not directly able to observe the incumbent's competency prior to voting. In addition, we assume that voters are unable to observe the incumbent's "regulatory zeal" (i.e., the level of regulation imposed by the incumbent), until the end of the period, when they observe the resulting environmental quality. This assumption seems reasonable insofar as regulatory enforcement, unlike environmental legislation, may be quite

[14]Because the incumbent's rent from office holding is constant, and because $\theta = 1$ for the type H incumbent, the expected rent term can be omitted from the incumbent's problem.

costly to observe. Finally, we impose the mild "normality condition" that

$$\frac{dx_1^*}{d\alpha_1} > 0, \tag{32}$$

where $x_1^* \equiv \text{argmax}_{x_1} R(x_1, \alpha_1)$.

Given imperfect information, rational voters will use all available information to form inferences about the leader's competency. Indeed, rational voters will likely be able to infer the differences between type H and type L incumbent's in equilibrium, because (in a separating equilibrium) type H incumbents will be willing to provide more consumption than type L incumbents, thereby signaling their higher competency and gaining reelection. As in Section II.B, we restrict our attention to sequential, separating equilibria in which voter inferences are Bayes-consistent.[15]

Looking first at period 2, the leader has no political incentive *not* to choose the efficient level of enforcement in that period, so that the incumbent's problem is the same as that in the full information case above. However, this no longer need hold in the first period.

Separating Equilibrium[16]

In a separating equilibrium, type H incumbents will distinguish themselves by providing levels of consumption higher than those of type L incumbents. In this case, the type L incumbent will follow his/her full information strategy, so that

$$x_1^{\mathrm{L}} = x_1^{\mathrm{LO}*}, \tag{33}$$

where x_1^j is the type j incumbent's equilibrium choice under asymmetric information.

To obtain the type H incumbent's equilibrium choice, first define A to be the set of first-period consumption choices that would *not* be beneficial for the type L incumbent to choose, even if he/she were able to secure reelection by doing so:

$$A \equiv \left\{x_1 | R\left(x_1, \alpha^{\mathrm{L}}\right) + \beta Z \leq D\left(x_1^{\mathrm{LO}*}, \alpha^{\mathrm{L}}\right)\right\}. \tag{34}$$

Also, define set B to be the levels of first-period consumption that it would benefit the type H incumbent to choose if by doing so he/she were able to secure reelection,

$$B \equiv \left\{x_1 | R\left(x_1, \alpha^{\mathrm{H}}\right) + \beta Z \geq D\left(x_1^{\mathrm{HO}*}, \alpha^{\mathrm{H}}\right)\right\}, \tag{35}$$

where $x_1^{\mathrm{HO}*} \equiv \text{argmax}_{x_1} D(x_1, \alpha^{\mathrm{H}})$.

[15] Let $\hat{\rho} = \hat{\rho}(x_1)$ be the voter's inference, based on the observable level of current consumption, concerning the probability that the incumbent is type H. In this context, $\hat{\rho}$ is Bayes-consistent if $x_1^{\mathrm{L}} \neq x_1^{\mathrm{H}}$ implies $\hat{\rho}(x_1^{\mathrm{L}}) = 0$ and $\hat{\rho}(x_1^{\mathrm{H}}) = 1$.

[16] We restrict our attention here to the case in which α_0 is observed, as would be the case if the incumbent had also held office in the previous period. Appendix E briefly explains why even stronger results follow when the incumbent faces reelection at the end of his/her first term in office.

From the definitions of A and B, it is clear that $A \cap B$ contains all possible separating equilibrium strategies for the type H incumbent. Assuming A is nonempty, we have:

PROPOSITION 3. *The set of all separating equilibria is nonempty and is characterized by* $x_1^L = x_1^{LO*}$ *and* $x_1^H \in A \cap B$.

Proof. See Appendix C.

As in II.B, we can reduce the range of separating equilibria to a unique *undominated* separating equilibrium by assuming voters are sophisticated enough that they will reelect the incumbent with probability one if $x_1 \in A \cap B$ and elect the opponent otherwise. Let $\tilde{x}$ be the upper bound of the open set A' (where A' is the complement of A). We have:

PROPOSITION 4. *There is a unique undominated separating equilibrium characterized by* $x_1^L = x_1^{LO*}$ *and* $x_1^H = \max\{\tilde{x}, x_1^{HH*}\}$.

Proof. See Appendix D.

Intuitively, the type L incumbent knows that it is not in his/her advantage to mimic the type H incumbent if the type H incumbent chooses $x_1 \in A \cap B$. However, the type H incumbent *will* set $x_1 \in A \cap B$, since by doing so the incumbent will win the election, obtaining utility that is higher than that if the opponent wins the election. Indeed, since the type H incumbent will win the election for *all* $x_1 \in A \cap B$, the incumbent will choose his/her most preferred element in this set. However, as long as Z is large enough, type H incumbents will not be able to distinguish themselves without departing from their full information strategy. In this sense, asymmetric information will, on average, result in an inefficiently low level of environmental quality.

IV. DISCUSSION AND CONCLUSIONS

This paper presents two very different perspectives concerning the formation of environmental policy. On the one hand, legislated abatement standards are probably more readily observable than the costs of such legislation. Not surprisingly, this can result in a bias favoring the enactment of overly strict environmental legislation—even in the context of a rational expectations model with representative agents. On the other hand, current consumption is probably more readily observable than the government's regulatory zeal. Insofar as the incumbent has discretion over the enforcement of legislated standards, there will likely be too little enforcement on average. Both biases probably exist in reality, with the net effect remaining an empirical question. On the one hand, the high public visibility of decisions over the Clean Air Act, or the Arctic Wildlife Refuge, may have prevented elected officials from forming policy on efficiency grounds.[17] On the other hand, environmental groups frequently win legal judgements against the

[17]This is not to say that these decisions were not correct. Rather the point is only that it is not surprising that elected officials reached these decisions, given the highly politicized nature of the debate.

government for failing to implement existing legislation with adequate zeal, suggesting that legislated standards are not always enforced.

The objective of this paper has primarily been to offer insights into the formation of environmental policy under asymmetric information. However, the analysis also offers insights into possible solutions.[18] Insofar as imperfect information results in a bias in *either* direction, it may be Pareto-improving to strengthen institutions for informing voters of incumbent behavior. For instance, the analysis suggests a need for improved research into the benefits and costs of environmental standards (along with improved dissemination of this information to voters). The analysis also suggests a rationale for right to know legislation, whereby voters can obtain information about (i) the polluting activities of government institutions and private firms and (ii) the regulatory activities of the government. Such laws will promote a clearer understanding of the magnitude of environmental problems, the magnitude of abatement costs, and the government's zeal in regulatory enforcement. Of course, right to know legislation will not automatically ensure full public awareness. There may also be important roles for private nonprofit environmental watchdog institutions, industry-financed and government-financed "think-tanks," and, perhaps most importantly, a vigilant media.

Another possible way to improve efficiency would be to rely more on private market solutions in cases where the conditions of the Coase theorem (approximately) hold (Coase [5] and Dahlman [6]). Private property solutions would not suffer from the biases identified in this paper.[19] When the conditions of the Coase theorem are not met, other, more voluntary, solutions may be effective. One example might be donations to nonprofit land conservancies. Another solution may be "green-consuming," whereby individuals factor environmental concerns into their private consumption decisions.[20] Both can help achieve environmental objectives while avoiding political biases. Of course, both solutions may suffer from the problem of free riding. To encourage these private initiatives, there may be a role for government subsidization of land conservation, or for government standards on environmental labeling of products.

When private solutions are not possible, either because of the high costs of private transactions or because voluntary solutions suffer from free riding, there may be governmental reforms that can help alleviate the problems identified in this paper. Insofar as the problem is insufficient information about abatement costs, it is interesting to note that some forms of regulation generate more information than others. In particular, transferable discharge permits can be expected to trade at prices equal to marginal abatement costs (absent noncompetitive behavior) (Tietenberg [16]). Or, insofar as the problem is excessive regulatory discretion by elected officials, it may be welfare-improving to rely more on

[18]Of course, as Rogoff observes, signaling has both costs (government policies are distorted) and benefits (voters are able to identify high-competency officials). However, the costs of environmental signaling would appear to outweigh any benefits in our model. The imposition of future costs by the incumbent is limited only by the incumbent's own desire to balance the rewards from office holding against his/her own concerns about the future. The psychic and financial gains from office are often considerable. Moreover, incumbents may be at least partially able to ignore future costs if they are able to live in areas with high environmental quality.

[19]For a recent analysis of these issues, see Anderson and Leal [1].

[20]See also Ostrom [13] and Bromley and Anderson [3] concerning voluntary environmental institutions.

government bodies less prone to political manipulation. For example, one might rely more on the courts.[21] Alternatively, one might entrust resource allocation decisions to "public trust" institutions, as when public land is designated as wilderness.[22]

To conclude, our purpose in this paper has been to identify a hitherto underresearched bias in government policy making associated with asymmetric information. Of course, the model is highly stylized and clearly neglects many other, potentially more important, sources of bias. Nevertheless, we find it interesting that bias can arise even in a frictionless world with rational, representative agents, as long as one makes what we feel are plausible informational assumptions. Hopefully, a better understanding of the biases in this simple model will help us to understand more complete models and help us to establish more efficient institutions for addressing environmental problems.

APPENDIX A: PROOF OF PROPOSITION 1

We begin by proving that $S \equiv A \cap B \neq \varnothing$. For this to hold it is sufficient to show that the set $[\tilde{a}, \bar{\tilde{a}}]$ is a nonempty subset of S (where $\tilde{a} \equiv \max A'$, as defined in the text, and where $\bar{\tilde{a}} \equiv \max B$). Because $V_2(\ )$ is concave in $\bar{a}_2$, $\Omega(\ )$ must also be concave in $\bar{a}_2$, so that the upper contour sets of $\Omega(\ )$ must be convex. However, from the definition of $\tilde{a}$, and because $\Omega(\bar{a}_2, \alpha^{\mathrm{H}}) > \Omega^{\mathrm{O}}(\bar{a}_2) > \Omega(\bar{a}_2, \alpha^{\mathrm{L}})$, $\forall \bar{a}_2$, we have

$$\Omega(\tilde{a}, \alpha^{\mathrm{H}}) + Z \geq \Omega^{\mathrm{O}}\left(\bar{a}_2^{\mathrm{HO}*}\right) \tag{A1}$$

(where we make use of the fact that $\bar{a}_2^{\mathrm{HO}*} = \bar{a}_2^{\mathrm{LO}*}$). Thus, $\tilde{a}$ must be in the interior of B, so that $[\tilde{a}, \bar{\tilde{a}}]$ is a nonempty subset of B. Also, we know that $[\tilde{a}, \bar{\tilde{a}}]$ is contained in A, because

$$\Omega\left(\bar{a}_2, \alpha^{\mathrm{L}}\right) + Z \leq \Omega^{\mathrm{O}}\left(\bar{a}_2^{\mathrm{LO}*}\right), \qquad \forall \bar{a}_2 \geq \tilde{a} \tag{A2}$$

(again using the concavity of $\Omega(\ )$ and the definition of $\tilde{a}$). Thus, $[\tilde{a}, \bar{\tilde{a}}]$ is a nonempty subset of S.

Given that $S \neq \varnothing$, we have the immediate result that choosing $\bar{a}_2 \in S$ would serve to distinguish a type H incumbent from a type L incumbent.

APPENDIX B: PROOF OF PROPOSITION 2

There are two main cases. First, if $\bar{a}_2^{\mathrm{HH}*} \in S$, then the type H incumbent can distinguish himself/herself from a type L incumbent by pursuing his/her first-best strategy. This will clearly be the incumbent's preferred strategy. If Z is large enough, however, we have the second case, in which $\bar{a}_2^{\mathrm{HH}*} \notin S$. In this case, we must show that $\tilde{a}$ is the incumbent's preferred strategy within S.

[21] The courts are clearly not immune to political manipulation, however.

[22] Wilderness areas are not entirely free from political manipulation, but the degree of manipulation is probably less than that with other forms of land management.

Complicating this proof is the possibility that S is made up of two disjoint subsets: $S = S_1 \cup S_2$, for $S_1 \equiv B \cap A_1$ and $S_2 \equiv B \cap A_2$, where $A_1 \equiv A \cap \{\bar{a}_2 \leq \bar{a}_2^{\mathrm{LL}*}\}$ and $A_2 \equiv A \cap \{\bar{a}_2 > \bar{a}_2^{\mathrm{LL}*}\}$, and where $\bar{a}_2^{\mathrm{LL}*}$ is the type L incumbent's preferred strategy given the certainty of reelection. If S_1 is empty, then the incumbent will clearly choose the least element of S_2 (i.e., $\tilde{a}$). (This is because $\tilde{a} > \bar{a}_2^{\mathrm{HH}*}$ if $\bar{a}_2^{\mathrm{HH}*} \notin S$ and because $\Omega(\ )$ is concave in $\bar{a}_2$.)

If S_1 is not empty, then we must show that

$$\Omega(\tilde{a}, \alpha^{\mathrm{H}}) > \Omega(\hat{a}, \alpha^{\mathrm{H}}), \tag{B1}$$

where we know that $\hat{a} \equiv \max S_1$ is the type H incumbent's most preferred element of S_1 (because $\bar{a}_2^{\mathrm{HH}*} > \bar{a}_2^{\mathrm{LL}*} > \hat{a}$ and because of the concavity of $\Omega(\ )$). Equation (B1) holds as long as

$$\Omega(\tilde{a}, \alpha^{\mathrm{H}}) - \Omega(\hat{a}, \alpha^{\mathrm{H}}) > \Omega(\tilde{a}, \alpha^{\mathrm{L}}) - \Omega(\hat{a}, \alpha^{\mathrm{L}}) \quad (= 0, \text{ from construction of } A). \tag{B2}$$

But (B2) must hold, because $\Omega(\bar{a}_2, \alpha_1) \equiv \rho V_2(\bar{a}_2, \alpha_1 + \alpha^{\mathrm{H}}) + (1 - \rho)V_2(\bar{a}_2, \alpha_1 + \alpha^{\mathrm{L}})$ and because

$$\frac{\partial^2 V_2(\bar{a}_2, \alpha_1 + \alpha_2)}{\partial \bar{a}_2 \, \partial \alpha_1} = \frac{1}{N}\frac{\partial^2 U_2}{\partial e \, \partial x} - \frac{c}{N^2}\frac{\partial^2 U_2}{\partial x^2} > 0 \tag{B3}$$

if e is a normal good. Thus, $\tilde{a}$ must be the type H incumbent's most preferred choice within S.

APPENDIX C: PROOF OF PROPOSITION 3

We begin by proving that $S \equiv A \cap B \neq \varnothing$. A sufficient condition for this is if $[\tilde{x}, \bar{\tilde{x}}]$ is a nonempty subset of S (where $\tilde{x}$ is defined in the text and where $\bar{\tilde{x}} \equiv \max B$). First, note that $R(\ )$, being the sum of concave functions, is itself concave. Thus, $R(x_1, \alpha^{\mathrm{H}})$ has convex upper contour sets for x_1. Also, note that

$$R(\tilde{x}, \alpha^{\mathrm{H}}) + \beta Z \leq D\left(x_1^{\mathrm{HO}*}, \alpha^{\mathrm{H}}\right). \tag{C1}$$

This follows from the definition of A and from $\Omega(x_1, \alpha^{\mathrm{H}}) > \Omega^{\mathrm{O}}(x_1) > \Omega(x_1, \alpha^{\mathrm{L}})$, $\forall x_1$ (and from the fact that $D(x_1^{\mathrm{HO}*}, \alpha^{\mathrm{H}}) > D(x_2^{\mathrm{LO}*}, \alpha^{\mathrm{L}})$). Thus, we have that $\tilde{x}$ must be in the interior of B, so that $[\tilde{x}, \bar{\tilde{x}}]$ is a nonempty subset of B.

Also, $[\tilde{x}, \bar{\tilde{x}}]$ is contained in A, because

$$R\left(x_1, \alpha^{\mathrm{L}}\right) + \beta Z \leq D\left(x_1^{\mathrm{LO}*}, \alpha^{\mathrm{L}}\right), \qquad \forall x_1 \geq \tilde{x}. \tag{C2}$$

Thus, we have $[\tilde{x}, \bar{\tilde{x}}] \subset S$.

From the definition of S, we have the immediate result that choosing $x_1 \in S$ would serve to distinguish a type H incumbent from a type L incumbent.

APPENDIX D: PROOF OF PROPOSITION 4

There are two main cases. First, if $x_1^{HH*} \in S$, then the type H incumbent can distinguish himself/herself from a type L incumbent simply by pursuing his/her first-best strategy. Since this is the incumbent's preferred strategy in the full information case, it will clearly be the incumbent's preferred strategy in the asymmetric information case as well. If Z is large enough, however, we have a second case, in which $x_1^{HH*} \notin S$. In this case, we must show that $\tilde{x}$ is the incumbent's preferred strategy within S.

Complicating the proof in this second case is the possibility that S is made up of two disjoint subsets: $S = S_1 \cup S_2$ for $S_1 \equiv B \cap A_1$ and $S_2 \equiv B \cap A_2$, where $A_1 \equiv A \cap \{x_1 \leq x_1^{LL*}\}$ and $A_2 \equiv A \cap \{x_1 > x_1^{LL*}\}$, and where x_1^{LL*} is the type L incumbent's preferred strategy given the certainty of reelection. If S_1 is empty, then the incumbent will clearly choose the least element of S_2 (i.e., $\tilde{x}$). (This is because $\tilde{x} > x_1^{HH*}$ if $\bar{x}_1^{HH*} \notin S$ and because $R(\ )$ is concave in x_1.)

If S_1 is not empty, then we must show that

$$R(\tilde{x}, \alpha^H) > R(\hat{x}, \alpha^H), \tag{D1}$$

where $\hat{x} \equiv \max S_1$ is the type H incumbent's most preferred element of S_1. (To see this, note that $x_1^{HH*} > x_1^{LL*} > \hat{x}$ and that $R(\ )$ is concave in x_1.) Equation (D1) holds so long as

$$R(\tilde{x}, \alpha^H) - R(\hat{x}, \alpha^H) > R(\tilde{x}, \alpha^L) - R(\hat{x}, \alpha^L)$$
$$(= 0, \text{ from the construction of } A), \tag{D2}$$

which is true if x_1 satisfies the normality condition in Eq. (32). That is, $dx_1^*/d\alpha_1 > 0$ implies

$$\frac{\partial^2 R(x_1, \alpha_1)}{\partial x_1 \, \partial \alpha_1} > 0, \tag{D3}$$

which in turn implies (D2). Thus, $\tilde{x}$ is the type H incumbent's preferred choice within S.

APPENDIX E: FIRST-TERM INCUMBENCY WITH DISCRETIONARY ENFORCEMENT

The main results reported in the text also hold for first-term incumbency. However, note that if an incumbent is in his/her first term, then α_0 will not be known by voters. Thus, in the unique undominated separating equilibrium, high-type incumbents will set $x_1 = \tilde{\tilde{x}}$, where $\tilde{\tilde{x}}$ is the largest element of set A computed for $\alpha_0 = \alpha^H$. Intuitively, incumbents with $\alpha_0 = \alpha^L$ and $\alpha_1 = \alpha^H$ will need to distort their enforcement decisions even more than identical incumbents with longer track records if they are to distinguish themselves from incumbents with $\alpha_0 = \alpha^H$ and $\alpha_1 = \alpha^L$. They can do so, however, because an incumbent with $\alpha_1 = \alpha^H$ has a higher expected competency than an incumbent with $\alpha_1 = \alpha^L$.

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