A Positive Model of Enforcement across Policy Domains

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ABSTRACT:

Regulatory agencies such as the FDA and EPA allocate limited enforcement resources across a number of competing areas (domains). However, there are no theoretical models that explain the determinants of agency enforcement priorities. The key question of this paper is whether agencies’ prioritization of different policy areas is better explained by a model where regulators maximize social welfare or one where special interest influence is also taken into account. We use the common agency approach of Grossman and Helpmann (1994) to build a model of environmental agency regulatory enforcement priorities that nests welfare maximization, special interest support, and budgetary factors. We hypothesize that the proportion of resources devoted to regulating a polluting industry rises if the: 1) pollution damage per unit of production increases; 2) political weight of environmental groups increases and the industry has lower price elasticity than other regulated industries; and 3) political weight of the industry decreases relative to the political weight of other regulated industries. We examine these hypotheses using panel data on 86 California local government environmental agencies over four years. The dependent variable suggested by the theoretical structure and institutional background of the empirical case is the relative inspection rate between the two most important programs (underground storage tanks and hazardous waste generators). The results support all three hypotheses. We examine whether interest group influence is important by including indicators of interest group homogeneity as regressors. We find that several indicators of homogeneity (such as industry concentration and moments of the income distribution) are as important to the relative inspection rate as measures of pollution and demand for environmental quality.
Introduction

In his seminal article, Stigler observed that the “costs of enforcing” contracts, laws, and specifically regulation, “has not received study by economists, despite its immense potential explanatory power” (1970:526) of economic behavior. Scholars responded with an explosion of normative analyses of enforcement, exploring the optimal design of monitoring and penalty regimes under a variety of conditions, and their implications for compliance regulation. However, there is little scholarship that explains the tremendous variation in the actual enforcement of regulations. This oversight is significant because it is not merely the design of a regulation but the extent of its implementation that produces actual social costs and benefits. While normative models allow for incomplete enforcement, they do not explicitly recognize that this incompleteness is highly systematic and the result of an optimization process by policymakers overseeing the implementation of policies across several domains. In the absence of positive models of enforcement, the “immense potential explanatory power” to which Stigler referred will remain elusive. We take a modest step towards achieving this goal by developing a common agency model of the policymaker’s enforcement allocation decision and then empirically testing the hypotheses using a unique data set.

We begin with the recognition that policymakers allocate scarce enforcement resources across competing policy responsibilities. The Security and Exchange Commission, Food and Drug Administration, Environmental Protection Agency, Federal Energy and Regulatory Commission, Occupational Safety and Health Administration and many other agencies have jurisdiction over several distinct policy areas. For the sake of convenience, most scholarship that evaluates the performance of a policy program assumes that policymakers in that agency will not substitute effort across policy domains. In contrast, we analyze how the policymaker’s substitution of enforcement resources across areas of responsibility varies with the structure of the political market for policy in each domain in which interest groups compete for policy advantage. We assume that the policymaker allocates scarce enforcement resources not only as a function of the social costs and benefits they produce, but also as function of the level of political market power of the interest groups affected by the enforcement of these policies. We explore factors that could affect the political market structure such as changes in the relative size, concentration or cohesiveness of interest groups.

Such a positive theoretical and empirical model of an agency’s internal allocation of resources can be useful to scholars and policymakers in several ways. Most generally, it identifies the determinants of policymaking behavior and measures their relative importance in policy outcomes. Policy reformers would be well advised to first acquire a deeper understanding of the determinants and dynamics of the existing policy process before endeavoring to redesign it. For instance, the recent push to decentralize water regulation enforcement (Pianin 2002) to the state level could benefit from an understanding of how the state-level political market structure of regulation would affect that attainment of regulatory goals. Such models also benefit scholars and policymakers interested only in accurately predicting policy outcomes. They could use such a model to anticipate how changes in the structure of interest-group competition within a policy domain will affect not only that policy domain, but also affect related programs under in the agency’s jurisdiction.

We employ a common agency model that assumes policymakers allocate resources across policy domains in response to a weighted sum of social welfare and political contributions from rival organized and unorganized groups. Formally, the model consists of two stages. In stage one, interest groups present a schedule of contributions as a function of the policy action(s). In stage two, the policymaker, acting as a common agent to the interest groups, maximizes a weighted sum of social welfare and contributions taking the contribution functions as given. We cast the model in terms of interests groups which typically influence environmental policy, although one could substitute those found in any one of a myriad of regulatory policy domains.
In the model, the policymaker allocates enforcement resources across two externality-producing groups, distinct polluting industries, in order to protect the externality-receiving group, an organized environmental group. We hypothesize that the policymaker responds to an increase in the aggregate demand for environmental quality across the two policy domains by increasing the share of resources devoted to the less price elastic industry. Second, a relative increase in the amount of an industry’s pollution per output (pollution intensity) will increase that industry’s share of enforcement resources. This model allows this same policymaker to give a positive weight to political contributions from organized interest groups. This results in our third hypothesis that an increase in the political effectiveness (cohesiveness and concentration) of the environmental interest group will increase the share of regulatory resources devoted to the less price-elastic industry. Fourth, an increase in the political weight (e.g. increases in cohesiveness and concentration) will increase the other industry’s share of enforcement effort.

Our empirical setting affords the opportunity to test two additional hypotheses that extend beyond my formal model. We hypothesize that when an industry produces two externalities of differing geographical scope, the policymaker will more efficiently manage the externality fully internal to his jurisdiction rather than one that is relatively more external to his jurisdiction. In my empirical context, policymakers are responsible for the enforcement of regulations on both air and water pollution sources. We expect policymakers to devote more resources to the program that primarily oversees water pollution sources, since water pollution tends to be more internal to the jurisdiction. This part of the research contributes to understanding cross-media pollution from the regulator’s point of view. Most research in this area (i.e. Alberini 2001, Sigman 1996) examines how regulation on pollution in one media may cause firms to shift pollution to another media. This dataset provides the opportunity to examine how the regulator allocates resources to different pollution domains—a necessary piece to piecing together a more complete picture of cross-media pollution.

We also hypothesize that the more homogenous the environmental and citizen groups the more effective they are politically. A key innovation of this paper is an attempt to include homogeneity and concentration variables that are associated with the ease of interest group mobilization. These variables distinguish the welfare-maximizing objective function from the weighted contribution and welfare objective function. Past research on enforcement has included establishment level data on affected firms, but none have focused on industry-level characteristics that may determine the extent to which the industry can affect policymakers. We include proxies for interest group mobilization both on the industry and environmental demand sides.

We test these hypotheses using panel data on 86 local agencies over 4 years in California. We model the determinants of enforcement effort across two hazardous waste programs: 1) underground storage tanks, and; 2) hazardous waste generators. Not only does the size and types of regulated industries vary across these three programs, but there is also considerable heterogeneity across industry and consumer groups in the 86 jurisdictions. The State of California defines the parameters of the regulatory programs (such as which facilities are covered and what an inspection entails), leaving each jurisdiction only the choice of the amount of effort to devote to each program. The dependent variable derived from the theoretical model is the ratio of inspection rates per unit of output between the two programs.

The results are consistent with the hypotheses generated from the welfare and contribution model of enforcement behavior. We find that indicators of group cohesiveness and concentration are both economically and statistically significant determinants of the relative prioritization of enforcement resources. Indicators of pollution intensity and demand for environmental quality are also economically and statistically significant. One positive implication of the results is that economists’ fears about the deleterious consequences of uniform regulatory standards may be overstated – in this case we show that actual implementation of regulatory standards varies quite a
bit with local conditions. However, the counterpoint is that the variation in enforcement appears to be influenced as much by the political market structure as by the social welfare consequences. This implies that further research should pinpoint how to implement regulatory systems that target enforcement resources to areas where the political strength of an interest group prevents the accomplishment of minimum regulatory goals.

**Background**

While theoretical approaches to modeling policymaking behavior have evolved considerably, few of these models have directly informed empirical hypotheses testing. The earliest models assumed an agency’s policymakers responded directly to the median voter while other, more sophisticated, nested, principal agent models explicitly recognized that agency policymakers existed in hierarchical relationship to elected legislative or executive overseers (ex., Weingast and Moran 1983). Neither of these two modeling approaches accommodates widely observed differences in the ability of constituents to organize into groups in order to lobby for their preferred policy outcomes. This led to the development of the external signal models that explicitly accommodated signals from both rival interest groups as well as political overseers (Noll 1985). However, the utility-theoretic foundations of the interest groups and the policymaker were ambiguous; and it applied to only one policy domain. In response, Grossman and Helpman (1994) developed the common agency model that posits the agency policymaker as the common agent to both organized and unorganized principals. This model was path breaking both because of its utility and game theoretic foundations and also for its general applicability to a multidimensional and multi-domain policy settings.

From the perspectives of empirical hypotheses testing, however, common agency models also have had two weaknesses. First, these models assume a strict distinction between organized and unorganized groups when in reality there is a continuum. Mitra (1999) develops a common agency model where interest group formation is endogenous, but once formed interest groups can set any feasible level of contribution from each member. Empirical implementations of the common agency model (Goldberg and Maggi 1999, Gawande and Bandyopadhyay, Mitra 2002) continue this assumption by modeling interest group formation as endogenous, but assume that, once formed, the interest group is able to enforce contributions. We introduce political mobilization variables that measure the proportion of the fully mobilized contribution that the interest group is able to gather. In the empirical section, we measure political mobilization with variables associated with the homogeneity and concentration of the interest group.

A second empirical challenge has been to identify falsifiable hypotheses from this very general theoretical model. The empirical evaluations of the common agency model have evaluated the relative importance of political contribution and social welfare by analyzing the extent to which policymakers favor more organized interest groups. Positive empirical models have explored a range of agency policy-making outcomes including agency rule making (ex., Cropper et al. 1992, Hakes 1999), program implementation (ex., Berrens 1999, May 1999), spending behavior (ex., Caplan 2001, Hughes 2000), and enforcement effort (ex., Olson 1996, Gray and Deily 1996, Helland 1998). Many of these studies test the null hypotheses that policymakers seek to maximize social welfare against alternative hypotheses such as seeking to maximize their chances of re-election or some other measure of personal utility.

There are two common weaknesses in the conventional empirical approach. First, most of these models lack a utility and game theoretical foundation for their hypotheses. This may lead to confusion about which explanatory variables are exogenous or endogenous. Second, many of these studies focus on only one of several programs implemented by an agency, and then implicitly ignore substitution possibilities on the part of an agency.

The common agency model of regulatory enforcement we present in the following section develops the rationale behind interest group political action, as well as the policymaker’s allocation...
of resources to different industries, from utility-theoretic foundations. There are two key differences between the common agency model developed here and those in the literature: 1) the introduction of political mobilization variables, previously mentioned; and 2) imposing a budget constraint on the policymaker’s choice set. Since enforcement costs money the agency choice should reflect the marginal value of funds in each program. The monetary cost of enforcement is a fundamental difference between modeling enforcement and tax-rate choice (the focus of the political economy common agency models) which may raise money. In the usual models, taxes or subsidies are endogenous decisions. In this model, there is an exogenous budget constraint, which is closer to the reality of most regulatory agencies. These additions to the normal common-agency model enable me to develop four testable hypotheses, which we test in the empirical section.

**Environmental Agency Political Maximization Problem**

We model a regulator who values both campaign contributions and social welfare. The first step is the development of a framework for how pollution control affects the owners of polluting industries and environmentally concerned individuals. Then we examine a game between a regulator and organized interest groups.

The context is a small, open economy where the prices of goods and labor are taken as fixed. There are four interest groups potentially affected by pollution regulation: environmentalists (externality-receiving individuals), owners of firms (or industry-specific factors) that produce pollution-causing goods $x$ and $y$, and citizens that are not affected by the externality and who do not organize. All groups have labor income net of taxes of $I-T$, while owners of sector specific factors have additional income from these sectors. Their utility maximization problems are detailed below (see Table 1 for definitions):

Environmentalist:

$$\max_{c_x,c_z,c_y} U^E = c_z + u(c_x) + u(c_y) - (\theta_x\bar{X} + \theta_y\bar{Y})$$

$$s.t. \ I-T+c_x+p_x c_x + p_y c_y$$

where $c_z, c_x, c_y$ are consumption of the numeraire and $x$ and $y$ goods, respectively. $\bar{X}$ and $\bar{Y}$ represent the total production of goods $x$ and $y$. $\theta_x$ and $\theta_y$ are the pollution intensities of goods $z$ and $y$. $p_x$ and $p_y$ are the world prices of goods $x$ and $y$.

Owner Industry $x$:

$$\max_{c_x,c_z,c_y} U^x = c_z + u(c_x) + u(c_y)$$

$$s.t. \ I-T+\rho_x(p_x)=c_z + p_x c_x + \hat{p}_y c_y$$

Where $\rho_x(p_x)$ is the revenue to owners of sector-specific factors for good $x$ and $p_x$ is the effective price to local owners after the effects of regulation.

Owner Industry $y$:

$$\max_{c_x,c_z,c_y} U^y = c_z + u(c_x) + u(c_y)$$

$$s.t. \ I-T+\rho_y(p_y)=c_z + p_x c_x + \hat{p}_y c_y$$

Unorganized citizen:
\[
\max_{c_x, c_y} U^c = c_x + u(c_x) + u(c_y) \\
\text{s.t. } 1-T=c_x + \hat{p}_x c_x + \hat{p}_y c_y
\]

Goods \(x\) and \(y\) are produced at constant returns to scale and the price of labor is normalized to 1. There are given world prices for the goods. Environmental regulation functions by decreasing the price received by owners of industry-specific inputs to \(x\) and \(y\) through fines and penalties for pollution (but does not affect the consumer price). Specifically, the price to the owner is given by:

\[
p_x = \hat{p}_x - r_x(e_x, \theta_x), p_y = \hat{p}_y - r_y(e_y, \theta_y)
\]

where \(p_x\) is the price received by owners of industry \(x\), \(p_y\) is the price received by owners of industry \(y\), \(\hat{p}_x\) is the world price of good \(x\), and \(\hat{p}_y\) is the world price of good \(y\). The per-firm monitoring and enforcement expenditures in each industry is given by \(e_x\) and \(e_y\). These equations assume that regulation has a decreasing marginal effect on the price received by the owner, i.e. \(\frac{\partial r_i(e, \theta_i)}{\partial e_i} > 0, \frac{\partial r_i(e, \theta_i)}{\partial \theta_i} < 0\) for \(i = (x, y)\). If there are increasing marginal costs of compliance, as is generally assumed in the monitoring and enforcement literature, then this assumption is justified.

Also, the effect of additional expenditures is assumed to increase with the pollutant toxicity \((\theta_i)\). This is likely if enforcement penalties are greater for violations of greater toxicity, or the likelihood of civil suits is greater. Another key aspect of this model is that monitoring and enforcement of regulation is costly and the agency has a fixed budget. This is a key aspect of the regulator’s problem and is also a new feature in common-agency models.

The common agency framework envisions a political decision-maker that maximizes a weighted sum of social welfare and contributions from the two industry groups and environmentalists. Unorganized citizens do not contribute. The agency’s maximization problem is:

\[
\max_{t_i, e_y} \Omega = \sum_{i=(x,y)} \gamma_i \Lambda^i(e_x, e_y) + w \Gamma^A(e_x, e_y), i \in [E, X, Y] \\
\text{s.t. } E_x + E_y = B, e_x \geq 0, e_y \geq 0
\]

where:

- \(\Gamma^A = l-T+N_x p(p_x)+N_y p(p_y)-N_E (\theta_x X + \theta_y Y)\)
- \(E_x = \text{Expenditure for regulating good } x\)
- \(E_y = \text{Expenditure for regulating good } y.\)
- \(w=\text{Regulator’s welfare weight.}\)

The \(\Lambda_i\) are the contributions from each of the organized constituencies if the constituency is completely mobilized (i.e. the interest group is able to enforce contributions, as assumed in GH), \(\gamma_i \in [0, 1]\) measures the ability of the constituency to organize, and \(\Gamma^A\) is the social welfare function. The regulator cares about both contributions as well as social welfare because both could influence his ability to keep his job and maintain or expand the independence of his agency.

Common agency is a two-stage game where principals first announce their bid function for the available policy actions. The agent (in this case the regulator or his political superior) takes the bid functions as given and then maximizes her objective function. GH show that a common agency equilibrium must (1) maximize the government decisionmaker’s utility; and (2) maximize, for each interest group, the sum of the government’s and interest group’s utility. These two properties combined imply that the marginal contribution will equal the marginal change in the interest group’s welfare due to a change in the distribution of regulatory effort.
\[
\frac{\partial \Lambda^i(e_x, e_y)}{\partial e_x} = \frac{\partial \Gamma^i(e_x, e_y)}{\partial e_x}, \quad \frac{\partial \Lambda^i(e_x, e_y)}{\partial e_y} = \frac{\partial \Gamma^i(e_x, e_y)}{\partial e_y}
\]

where \( \Gamma^i(e_x, e_y) \) is an indirect utility function for each of the \( i \) interest groups.

Using this relationship and the government’s maximization problem we have the F.O.C.’s:

\[
\sum_{i = (x, y)} \frac{\partial \Lambda^i(e_x, e_y)}{\partial e_x} + \frac{w \partial \Gamma^i(e_x, e_y)}{\partial e_x} = \lambda \left( \frac{dE_x}{de_x} \right) \quad \text{or} \quad e_x = 0
\]

\[
\sum_{i = (x, y)} \frac{\partial \Lambda^i(e_x, e_y)}{\partial e_y} + \frac{w \partial \Gamma^i(e_x, e_y)}{\partial e_y} = \lambda \left( \frac{dE_y}{de_y} \right) \quad \text{or} \quad e_y = 0
\]

\[E_x + E_y = B\]

These equations state that the optimum regulation/unit of production is set so that the marginal contribution gain plus marginal welfare gain due to a change in regulation equals the shadow value of funds times the marginal additional administrative expenditure.

The budget constraint fixes the level of welfare of the unorganized citizens so that they have no effect on the distribution of regulatory resources. The regulator considers the welfare and contributions of the four groups. However, the unorganized citizens are not affected by pollution amounts (it does not enter their utility function). Also, since regulation does not affect the price of the goods, the unorganized consumer is not affected through that channel. In this model, the only way the unorganized citizens’ welfare (and therefore contributions) would be affected is through a change in taxes. But in this model of regulatory decision-making the tax level is fixed. The contribution-motivated agency decisions then have no effect on the welfare of the unorganized citizens. In previous papers on common agency, it is generally argued that the organized interest groups benefit at the expense of the unorganized groups. However, in this model, because of the budget constraint, the organized interest groups compete with each other to sway the policymaker.

We can restate the F.O.C’s to gain further insight into the regulator’s problem:

\[
\frac{MNB_y}{MC_y} = \frac{MNB_x}{MC_x}
\]

Where:

\[
MNB_y = \frac{\theta_1[\phi \theta_1 y_p - (1 + w \gamma_y) y]}{e_y}, 
MNB_x = \frac{\theta_1[\phi \theta_1 x_p - (1 + w \gamma_x) x]}{e_x}
\]

\[
MC_y = y - \theta_y y_p, 
MC_x = x - \theta_x x_p
\]

\[
\phi = NE(1 + w \gamma), x_p = \frac{\partial x}{\partial p_x}, y_p = \frac{\partial y}{\partial p_y}
\]

Additional regulation of industry \( x \) or \( y \) increases welfare and contributions from environmentalists but decreases welfare and contributions from the regulated industry. The difference between these two marginal changes is the marginal net benefit (MNB) to the regulator of additional regulation on the good. The marginal cost (MC) denominator of each side is the additional expenditure resulting from an increase in regulation. Equation 3 states that the regulator sets tax rates to equalize the marginal net benefit per dollar of additional expenditure.

We can re-express the result in terms of the ratio of regulatory effort \((e_y, e_x)\) and the elasticities of regulation \((\varepsilon, \varepsilon')\):
Eqn. ref: regulation ratio states the ratio of regulatory effort per unit of production of $x$ to regulatory effort per unit of production of $y$. The elasticities of regulation are the percent change in the quantity of the good supplied due to a percent change in regulatory effort ($e_y, e_x$). A key assumption is that additional regulation (increased $e_y$ or $e_x$) always increases the total cost of regulation. This implies $e_y, e_x \in [-1, 0]$.

**Comparative statics:**

We assume that the regulatory effort elasticities are constant (following Fredriksson, 1997) and examine how the ratio of resources changes with variation in the parameters ($\theta, NE(1 + \gamma_E), \gamma_x, \gamma_y$). Proposition 1 formally describes how the regulatory resource ratio changes with an increase in the pollution intensity of an industry.

**Proposition**: The share of resources to regulate $x$ will increase with the pollution intensity of $x$, ($\theta_x$) and decrease with the pollution intensity of $y$, ($\theta_y$), ceteris paribus.

$$\frac{\partial R}{\partial \theta_y} > 0, \frac{\partial R}{\partial \theta_x} < 0$$

The proof is in Appendix 2.

The pollution intensity could refer to the toxicity of pollution or the proportion of pollution from the industry that impacts the decision-making jurisdiction. For example, in the cities and counties we consider in the empirical portion of this paper, it is likely that a significant portion of air pollutants travel outside the jurisdiction. Water pollutants do not tend to travel as fast. Therefore, if one industry tends to have a higher proportion of air pollution than the other, it would tend to have lower pollution intensity.

**Proposition**: The share of regulatory resources devoted to an industry will decrease with its own political weight and increase with the political weight of other polluting industries:

$$\frac{\partial (R)}{\partial \gamma_x} > 0, \frac{\partial (R)}{\partial \gamma_y} < 0$$

Proof: Appendix 2.

The intuition is straightforward; the more organized and politically effective the industry, the smaller the proportion of resources devoted to regulating it.

The political regulator responds not just to the number of environmentalists but also to their ability to organize. We can think of the quantity $\phi_E = NE(1 + \gamma_E)$ as the weight of the environmental interest group in agency decisionmaking. Proposition 3 examines how an increase in the strength of the environmental lobby changes the ratio of effort devoted to firms in each industry. However, we first establish the difference between the political regulator and a regulator whose goal is solely pollution minimization, i.e., a regulator with the following objective function:
\[
\max_{\Omega} \Omega = -(\theta_x X + \theta_y Y) \\
\text{s.t. } E_x + E_y = B, e_x \geq 0, e_y \geq 0
\]

**Lemma** The pollution minimizing regulator will set the ratio of regulatory effort as follows:

\[
\frac{\theta_y \epsilon^*_y}{(1 + \epsilon^*_y) e_y} = \frac{\theta_x \epsilon^*_x}{(1 + \epsilon^*_x) e_x}
\]

Comparing this ratio to the politically-maximizing regulatory ratio, we find:

**Lemma** Let \( R^p = \frac{e_y}{e_x} \) for the political regulator, and \( R^l = \frac{e_y}{e_x} \) for the pollution minimizing regulator, and let (without loss of generality) \( \frac{\epsilon^*_y}{(1 + w' \gamma'_y)} > \frac{\epsilon^*_l}{(1 + w' \gamma'_x)} \) (i.e. with equal industry weights \( x \) is more regulation-elastic). Then \( R^p > R^l \).

**Proof** See Appendix 2.

using the conditions for an interior solution and the assumption that increased per-firm regulation always increases total costs, simple algebra proves Lemma 2.

These two lemmas show that the pollution minimizing regulator will impose lower relative regulation on firms in the industry with higher weighted regulation elasticities than the politically-motivated regulator. Further, it can be easily seen that taking the limit of \( R^p \) as \( \phi_E \) goes to infinity results in the pollution-minimizing regulatory ratio. Therefore, we would expect increases in environmental strength to result in more regulation for firms in the industry with lower politically-weighted regulation elasticities.

The key difference between the pollution-minimizing regulator and the politically-motivated regulator is that the politically-motivated regulator considers both the welfare and contributions from industry by increasing the regulation on firms in the industry with lower weighted regulation elasticities. Therefore, to understand the regulator’s decisionmaking we should look at the effect of changes in shares of regulatory resources at the pollution-minimizing ratio on net industry welfare.

**Lemma** Let the sum of industry welfare be \( IW = \Gamma^X(e_x, e_y) + \Gamma^Y(e_x, e_y) \). At \( R^l \), \( \frac{\partial IW}{\partial e_y} > 0 \), holding expenditure constant, if \( y \) is more regulation-elastic. The opposite holds true if \( x \) is more regulation-elastic.

**Proof** Holding expenditure constant implies that \( \frac{\partial e_x}{\partial e_y} = -\frac{N_x \theta_x}{N_x \gamma_x (1+e^*_x)} \frac{e_x}{\epsilon_x} - \frac{N_y \theta_y}{N_y \gamma_y (1+e^*_y)} \frac{e_y}{\epsilon_y} \). Substituting this into the derivative \( \frac{\partial IW}{\partial e_y} \) we obtain \( \frac{\partial IW}{\partial e_y} = \frac{N_x \theta_x}{N_x \gamma_x (1+e^*_x)} \frac{e_x}{\epsilon_x} - \frac{N_y \theta_y}{N_y \gamma_y (1+e^*_y)} \frac{e_y}{\epsilon_y} \). The condition for \( \frac{\partial IW}{\partial e_y} > 0 \) is that \( \frac{\epsilon_y}{\epsilon_x} > \frac{\theta_y (1 + e^*_y)}{\theta_x (1 + e^*_x)} \). So until this ratio is reached the regulator increases the welfare and contributions from industry by increasing the regulation on \( y \). A few steps show that \( \frac{\theta_y (1 + e^*_y)}{\theta_x (1 + e^*_x)} < R^l \) if \( e_x > e_y \). I.e. if \( y \) is more regulation elastic, than at \( R^l \) net industry welfare increases with an expenditure constant increase in \( e_y \). Q.E.D

This Lemma shows that at the pollution-minimizing ratio, the political regulator sees that increasing the share of expenditures going to the regulation of the more regulation-elastic industry will increase industry welfare as well as contributions. The political regulator devotes an even greater share of resources to the relatively more elastic industry than the pollution-minimizing regulator because it is relatively easier to extract contributions/raise welfare from the more elastic.
industry at the pollution-minimizing resource ratio.

**Proposition** : An increase in the environmental weight will increase the share of regulatory resources devoted to the less pollution elastic industry, where each elasticity is weighted by its organization ability.

\[
\frac{\varepsilon_i^y}{1 + w\gamma_y} > \frac{\varepsilon_i^x}{1 + w\gamma_x} \Rightarrow \frac{\partial(R)}{\partial \phi_E} > 0
\]

*Proof: Appendix 2.*

This result may at first seem counter-intuitive; intuition suggests that increased environmental strength should result in increased regulation of the more regulation-elastic industry, since this industry will decrease pollution more in response to a regulatory increase. However, as we discussed, the political regulator overshoots the pollution minimizing regulatory ratio by regulating the more-elastic industry to a greater extent than the pollution-minimizing regulator. While the political regulator loses some contributions and welfare from the environmental group by targeting the more regulation-elastic industry to a greater degree than the environmentalist group would prefer, she is more than compensated for the loss by gaining contributions.

The proposition shows that as \(\phi_E\) increases, the regulator gradually shifts resources to get to the maximum pollution reduction possible given his budget constraint. This implies a shift towards the regulatory ratio implied by Eqn. ref: regulation ratio.

The next proposition follows from the logic behind proposition 5.

**Proposition (Political Regulation)** : If \(y\) is the more regulation elastic industry, the cross partial

\[
\frac{\partial^2(R)}{\partial \phi_E \partial \theta_y} > 0 \quad \text{and} \quad \frac{\partial^2(R)}{\partial \phi_E \partial \theta_x} < 0. \quad \text{The reverse is true if} \ x \ \text{is more regulation elastic.}
\]

*Proof* : Appendix 2.

The regulator avoids a loss of contributions from industry while coming close to his pollution reduction goals by increasing the regulation on the elastic industry. An increase in the pollution intensity of the more regulation elastic industry increases the pollution reduction from the regulation elastic industry further, increasing the regulator’s incentive to regulate that industry.

Propositions ref: pr_indpw, ref: pr_envwgt and ref: pr_xenvwgt both state hypotheses concerned wholly or partially with the effects of political weight on the regulatory resource distribution. The key to determining the relative influence of welfare and political organization concerns is defining variables that are likely to be related to political organization ability and unlikely to be related to the welfare effects of the regulation. We focus on indicators of the interest group’s concentration and homogeneity. We go over the specific variables below, after first discussing the background for my empirical tests.

**Empirical Background**

In California, all 58 counties and 28 cities are the frontline monitors of hazardous waste producing industries. There are three major hazardous waste programs (underground storage tanks (hereafter tanks), hazardous waste generators, and safety plans). For these programs, the local jurisdictions have been monitoring and enforcing state-written regulations designed to limit the emissions of toxic wastes since 1997.

The underground storage tank program mainly affects the retail gasoline industry, since almost all tanks are located in retail gasoline stations. Several programs monitor different types of hazardous waste generators. We concentrate on the standard hazardous waste generator program (hereafter, generator program) because it garners the majority of regulatory resources devoted to hazardous waste generators. The generator program is mainly composed of firms in industries such as petroleum refining, chemicals, dry cleaning, printing, pulp and paper, and others. Safety plans
are required for almost any firm that handles even small quantities of hazardous waste. Industry coverage overlaps with the coverage of the generator program, but also includes many smaller firms. Most manufacturing establishments are covered by safety plan requirements.

The three programs together take up the lion’s share of local government hazardous waste regulation resources in California. On average, 29% of total inspection hours are spent in the generator program, 39% in the safety plan program, and 28% in the tank program. We restrict our analysis to just the generator and tank programs. The safety plan program does not require adjustments that affect firm operations or marginal costs (inspections only check the existence of an adequate safety plan), and therefore doesn’t fit within the modeling framework.

**Data and Hypotheses**

In this section, we discuss the observable empirical variables used to capture the relevant factors suggested by the theoretical model, as well as the predicted influence on the distribution of regulatory resources. The basic data are the numbers of inspections and establishments in each of the three programs from 1998-2001. There are a total of 86 jurisdictions (58 counties and 28 cities) observed over the 4 years of data for a total of 344 possible observations, though only 248 observations are used in the estimation because of missing observations or missing variables. We use the inspection rate per establishment as a proxy for the theoretical variable “inspections per unit of production.”

The unit of analysis is a jurisdiction (city or county) and the logged ratio of the inspection rates is the dependent variable suggested by the theoretical model in equation ref: regulation ratio. We pick the logged ratio of inspection rates over other alternatives such as the regulatory program’s share of the overall regulatory rate or the inspection rate for each program because an unknown parameter, the “regulatory elasticities” enter into the inspection rate ratio in a straightforward manner. In a share or absolute inspection rate model, the regulatory elasticities and budget variables would enter together as a complex nonlinear function, complicating the empirical analysis. In the future it may be desirable to examine share or absolute rate equations. However, for this paper’s goals, examining the ratio of inspection rates is sufficient.

Several propositions involve the pollution intensity of production. Pollution intensity includes any variable that increases the disutility to the environmentalist constituency from production in that industry. We expect the pollution intensity of production in the tank program to increase the tank establishment inspection rate relative to the rate for generator establishments (from proposition ref: pr_pollint). We use 2 variables to capture the pollution intensity of tank establishments: 1) the agency-level moving sum, over the preceding three years, of the average number of tank leaks per facility per year; and 2) the agency level moving sum, also over the preceding three years, of the average quantity leaked per facility per year.

For the hazardous waste generator program, we consider several measures of pollution intensity. The EPA TRI database catalogues the majority of hazardous waste emissions from the industries covered by the generator program. From this database, we derive the total emissions of hazardous waste in each jurisdiction in each year from 1995-2000. However, this measure does not take into account differing toxicities of different pollutants. We used the EDF methodology (Hertwich, et. al 1998 ) to calculate a total cancer score per establishment in the generator program for the pollutants in each jurisdiction. Cancer risks are likely to be incorporated into the mortality risk measures that environmental and public health agencies use. We use a moving sum, over three years, of the jurisdiction cancer score/firm variable to partially represent generator pollution intensity. Also, we use a moving sum, over three years, of the jurisdiction per-facility average amount of waste emitted to water as an additional proxy for pollution intensity. We use a moving sum, over three years, of ERNS reported yearly average (over each jurisdiction) incidents/establishment, to capture other indicators of pollution intensity, not adequately represented
in the TRI data.

The relative political weight of industries and environmentally active citizens is predicted to play an important role in determining the distribution of regulatory resources. Proposition ref: pr_envwgt predicts that increased environmental weight will lead to a shift in regulatory resources to the less regulation-elastic industry. We have no a priori belief as to which industries are relatively less regulation elastic, thus we cannot predict whether increased environmental weigh will lead to relatively more inspections in the tank or generator program. However, we do expect that all variables that increase environmental weight to have identical signs to each other. For the environmental interest group, the indicators of the strength of environmental preferences are the percentage of voters voting for environmental propositions, population density, and dependence on private water wells and median household income. Environmental proposition voting is likely to be correlated with environmental sympathies. Higher population density areas are likely to suffer more from a given amount of pollution. Dependence on private wells may be important because many types of emissions affect water supplies and water extracted from public wells can be more easily treated to remove any problems. In jurisdictions that are relatively more dependent on private wells, a higher percentage of the population is likely to be concerned with pollution.

Environmental strength is partially a function of the ability to organize (Percorino, 1999; Conley and Dix, 1999). Common proxies for organizational capacity include measures of heterogeneity among citizens and industry concentration. As indicators of environmental political weight, we use the variability and skewness of the income distribution derived from the 2000 census household income data. Since greater heterogeneity of the environmental interest group is predicted to decrease environmental weight, we expect the coefficients of these two variables to be identical to each other and the opposite of the sign of the other environmental weight variables above. These variables, since they are associated with political weight rather than welfare effects, are also key to distinguishing the “political” vs. “benevolent” regulator.

Proposition ref: pr_indpw leads to the hypothesis that increased political organizational ability of industries covered by the tank program should shift regulatory resources toward the generator program. A long literature argues that interest groups with more concentrated benefits from political action are more likely to mobilize contributions to affect political actions. Also, as an interest group is a greater share of the jurisdiction’s population, it may be able to organize more effectively by taking advantage of economies of scale/scope in political action.

As indicators of the political mobilization of the retail gasoline stations covered by the tank program, we use the percentage of the labor force in the retail gasoline sector and the percentage of gas stations that are branded (not independent). The percent branded is likely to increase the political weight of the retail gasoline industry since large chains are more likely to be able to overcome free-rider problems and achieve political goals. We expect these measures to decrease the relative inspection rate of the tank program.

For the generator program, we use a Herfendahl index of pollution concentration (see Appendix 3) and the percentage of employees in hazardous waste industries as indicators of political weight. Usually, the output market (such as the value of sales of the final product) defines concentration. However, in this case a better measure of concentration is the concentration in the actual output of pollution. We hypothesize that if pollution in a jurisdiction is concentrated among a few large firms, they will be better able to mobilize and will have a greater political weight. Thus, we predict that a higher concentration of hazardous waste output will lead to a shift in resources away from the generator program. If variables such as the pollution concentration and employment percentages are economically and statistically significant, this would support the “political” regulator model.

An additional hypothesis concerns the interaction of pollution-intensity and environmental weight variables (from proposition ref: pr_xenvwgt). If the dependent variable is the log of (inspection rate x/ inspection rate y) and the environmental weight variables have a negative sign
indicating they shift resources towards $y$), this indicates that industries under program $y$ have lower “regulation elasticity (= elasticity of output with respect to the pollution level).” Then, we hypothesize that the interaction of environmental weight variables (percent green, population density, median income, and private water) with the pollution intensity variables from $x$ would have a negative sign and the interaction with pollution intensity variables from $y$ would have a positive sign (see Proposition ref: pr_xenvwgt for explanation).

We expect water pollution measures to in general be more significant to local regulatory behavior than air pollution. Air pollution has a less localized effect than water pollution and, therefore, local jurisdictions will have a smaller incentive to regulate air pollution sources than water pollution sources. We decompose emissions from the TRI and ERNS databases into those that affect water and those that affect soil. We cannot decompose tank leaks into water or air categories, but generally they affect water and/or soil rather than air quality.

**Econometric model**

To test these hypotheses, we used a linear random effects panel data model for unbalanced panels. This estimation equation could be derived from a Taylor series expansion of the inspection rate equation. The dependent variable is log(inspection rate tank/inspection rate generator).

We use a random effects estimator because my number of cross-sectional entities is large relative to the number of time-series observations and we have several important variables that do not vary over time. In the results section, we present a Hausman test of the key random effects assumption that the panel-specific error is independent of the RHS variables. If this assumption is rejected, a fixed effects specification would be more appropriate.

Since the jurisdictions range in size from tiny Vernon (pop. 548) to Los Angeles County (pop. 9,587,343), it is possible that heteroskedasticity will affect the results. We present a likelihood-ratio test of the usual homoskedasticity assumption that shows heteroskedasticity is likely present. We adjust for this by using a robust estimator (Huber/White) for the standard errors of the random effects model that allows for the possibility that the variance of the combined standard error differs over panels. The robust covariance estimator does alter the significance of the results (in some case up, in some cases down), but does not change the estimated coefficients.

**Results**

The results of the regressions are in general agreement with the hypotheses from the political model of regulator behavior. Increases in an industry’s political weights are associated with a reduction in that industry’s inspection ratio and this effect is significant. Also, increases in an industry’s pollution intensity variables generally increase that industry’s inspection ratio and are usually significant. Finally, the environmental weight variables all have the same signs, as predicted. These latter two results are consistent with a “benevolent” or “political” regulator.

We present four regressions in Table 2. Regressions (1) and (2) are for the period 1998-2001. Regression (1) presents a base regression and (2) breaks down the generator pollution intensity variable by air/water. Regressions (3) and (4) check the robustness of the specification by running the specification separately for time periods 1999-2001 and 2000-2001.

It is not a priori certain whether the assumptions of the random effects model are satisfied in these specifications. The first possibility is that the variance of the individual effect is heteroskedastic. We use a GLS specification to test this assumption with a likelihood ratio test, and we reject the null of homoskedasticity at the 1% level. We also test the null hypotheses that the errors are not systematically related to the regressors with a Hausman test. We do not reject the null for regression (1) ($p = .17$). This test suggests that the random effects model is acceptable for these specifications. The robust regression we present does not calculate $R^2$, but to give a general idea of
goodness of fit, the $R^2$ for the homoskedastic version of regressions (1) is 0.22. In the following
discussion we will refer to the results of regression (1) unless otherwise specified.

**Environmental Political Weight**

The hypothesis from the theoretical model is that the marginal effects of the variables that
increase environmental demand should all have identical signs to each other. Population density,
private water usage, environmental proposition voting are all expected to increase demand so
therefore they should have identical signs. Income variance is expected to decrease demand and so
therefore its coefficient should be the opposite sign from the other environmental demand variables.

Table 3 shows the marginal effects (at the medians of the variables) taking into account
interaction effects, and the prediction seems to be confirmed, the four variables associated with
higher environmental demand all have negative marginal effects while income variance has a
positive marginal effect. The coefficient on the population density variable is negative, the
environmental proposition voting coefficient is negative, and the median income coefficient is
negative and all three are significant at the 1% level. Finally, the private water usage coefficient is
negative and jointly significant with the coefficient on its interaction (with air release incidents) at
the 5% level.

According to propositions ref: pr_envwgt and ref: pr_indpw, the negative signs on the
coefficients of the environmental weight variables indicate that either 1) the regulation-elasticity of
output in the industries in the generator and safety plan program is less than the regulation elasticity
of retail gasoline; and/or 2) the political organization of the retail gasoline industry is greater than the
organization of the generator firms. It is difficult to guess at the relative regulation elasticities of the
two groups of firms. However, both casual observation and the empirical results point to a higher
degree of political organization of the gasoline industry. The retail gasoline industry is far more
homogenous than the range of generator firms, is well represented by various lobbying groups, and
has other common interests besides environmental regulation. In contrast, generators come from
many separate industries. In addition, the elasticities of the inspection rate ratio to the retail gasoline
political weight variables (Table 4) are far greater than the elasticities of the generator political
weight variables (at the medians of all variables), indicating that the political organization and
effectiveness of the retail gasoline industry may be higher.

**Pollution Intensity**

Another hypothesis is that a higher pollution intensity of firms covered by a program will
result in relatively high inspection rates. The results support this hypothesis. The pollution intensity
variables for the tank program are agency-level average number of leaks/per firm and average
amount of emissions/firm over the last 3 years. The total leaks coefficient is significant, and, taking
into account interaction effects, the marginal effect is positive, supporting the hypothesis. If the
linear term and all interactions of total quantity emitted variable are considered jointly, the marginal
effect is positive (Table 4), as expected, and the coefficients are jointly significant at the 1% level.

The pollution intensity variables for the generator program are the average cancer risk score per
generator establishment over the past 3 years, total water releases/firm, and total hazardous waste
releases to the air per firm from the ERNS database (the one with wider coverage). We expect all
marginal effects to be negative since higher pollution intensity in the generator program should shift
regulatory resources towards the generator program and reduce the tank/generator inspection ratio.
The joint marginal effect of the linear cancer score variable and its interaction with the proposition
voting variable is negative, as expected, and the coefficients are jointly significant at the 1% level.
The coefficient on air incidents is negative but insignificant.

Proposition ref: pr_envwgt states that the derivative of the inspection ratio with respect to
environmental weight will decrease with increasing generator pollution intensity and decreasing tank
pollution intensity. This leads to the prediction that the interaction of the environmental weight and generator pollution intensity variables should have a negative coefficient, and the interaction of environmental weight and tank pollution intensity variables should have a positive coefficient. The coefficient on the interaction of environmental proposition voting with the cancer score/firm is negative, as predicted, and significant at the 1% level. The coefficient on the interaction of air incidents/firm with private water is positive, contrary to the prediction, and significant at 5%.

A possible explanation of this contrary finding is that, instead of preferences over a uniform environmental good, the environmentalist constituencies may have separate preferences over air and water quality whose relative strengths differ depending on local factors. If air and water quality do enter separately into the environmentalist utility function, we could interpret the private water variable as representing demand for water quality rather than demand for overall environmental quality. Under this assumption, it is not surprising that the marginal effect of the private water variable increases with the average number of air incidents per firm. Where the number of air incidents/firm is higher, this indicates that the pollution from generator firms has a large effect on air quality relative to water quality (holding water emissions/firm constant). Then, environmentalist constituencies with relatively strong demand for water quality (as indicated by high levels of the private water variable) would be relatively more concerned with the level of regulation on tank firms, whose pollution mainly affects water/soil. This raises an interesting issue that perhaps the theoretical model should be adjusted to allow for environmental groups to place a separate values on air and water pollution.

We test the prediction that the marginal effect of environmental weight variables should increase with increasing tank pollution intensity by interacting the average tank emissions amount/firm with population density, private water, and median income. The coefficients indicated that the marginal effect of population density, private water, and median income are greater in jurisdictions with higher average tank emissions per firm and the effect is significant at the 5% level. In addition, we interact the income variance variable with the average number of leaks/firm. We expect the marginal effect of average leaks/firm to decrease with increasing income variance. We find that the marginal effect of leaks/firm is lower in jurisdictions with high income variance, and the effect is significant at the 1% level.

In all but one case, the predicted change in the marginal effect of the environmental weight variable due to a change in the level of pollution intensity is supported by the results. That one exception (the interaction of air pollution incidents/firm with private water) has a plausible explanation concerning differential demand for air/water quality. Below we examine the issue of distinct air and water quality preferences.

**Industry political weight**

The industry weight variables for both tanks and hazardous waste generators are all significant and of the expected signs. The results suggest that an increase in the political weight of the industries covered by a program will shift regulatory resources away from that program. The statistical significance of the political weight variables implies that regulators are, to some degree, contribution-maximizing. (i.e., they consider political as well as welfare maximizing criteria.)

The variables representing the political weight of generator industries are the percentage employment in hazardous waste industries and the concentration measure for hazardous wastes emitted to water. The coefficient on the percent of hazardous waste employment is positive, as expected, but insignificant. We find that the coefficient on pollution concentration is negative and insignificant. The interaction of concentration with a county dummy has a positive coefficient, as expected, and is significant at the 5% level. Taken together, these results indicated that increased pollution concentration has an insignificant effect at the city level but increases the inspection ratio (relatively more inspections for tanks) for counties. This is not surprising since previous research
(Cutter 2001) indicates that the city-based agencies in the dataset are more environmentally aware than the counties and thus possibly less responsive to industry lobbying.

The variables for the political weight of the retail gasoline industry (associated with the tank program) are the percentage of employment in the retail gasoline sector and the percent of stations in a jurisdiction that are owned or franchised by a major brand. The coefficients of these variables are negative and significant at the 1% level. This indicates that a higher political weight for the retail gasoline industry increases the relative number of inspection for generators, as predicted.

**Air vs. Water Quality**

Water quality is a public good that is more local in scope than air quality. Regulators at the city or county level may recognize that benefits from water regulation are more likely to accrue exclusively to their constituents than benefits from air regulation. Therefore, regulators may well pay more attention to pollution that affects water. In addition, the institutional structure of regulation recognizes that air quality needs to be regulated at higher levels of government and, in California, air quality is often regulated at the regional level, with additional state and national levels of regulation. This institutional structure implies that air polluters 1) may have less need to influence local regulators who may not be overly concerned with air quality; and 2) may focus on regional or national level regulators to achieve their desired regulatory outcomes.

For the tank program, all emissions overwhelmingly affect water or soil, so there is no air/water issue. However, for the generator program we can separate out emissions counted by the TRI dataset into those that go to water or air. In regression (2) we add the average air emissions/firm to the specification in regression (1) and find that the coefficient is insignificant. This suggests the regulators are more concerned with water emissions. We would also like to perform this test for the ERNS dataset. However, this dataset reports very few water incidents (almost all jurisdictions have zero), probably because it relies on third-party reports and leaks to water are difficult to observe.

We can also define a pollution concentration index for all pollutants and for pollutants that go solely to water. In regression (2), we define concentration over all pollutants, and, the coefficients for this variable and the interaction of concentration with the county dummy are insignificant. In regression (1), we define concentration over just water pollutants, and find the county interaction coefficient is quite significant. The comparison between regression (1) and regression (2), while not definitive, suggest that local regulators are more responsive to water pollution and water polluters exert comparatively more effort on local regulators than air polluters do.

**Relative Contribution of Welfare-Maximizing and Political Organization Variables**

The previous results show that political organization variables are statistically significant, but do not address the relative contribution of these variables compared to the contribution of variables that are expected to influence a welfare-maximizing regulator. We examine the relative contributions of these variables by looking at the elasticity of the inspection ratio with respect to each variable (at the medians of all variables), taking into account all interactions.

The political organization variables for the tank program (% employment in retail gasoline and % branded) have fairly high elasticities, -1.03 and -1.47 respectively. However, the political organization variable for generators (% employment in hazardous waste industries and concentration in water pollution output) have low elasticities, .008 and, 0.148 (counties) and -.096 (cities), respectively. The difference could be explained by the relative homogeneity of the retail gasoline industry.

We see a similar difference in elasticities between tank pollution intensity and generator pollution intensity variables (again, evaluated at the medians of the variables). The elasticities for
generator pollution intensity variables are all less than .1 in absolute value. The elasticity for tank leaks/firm is 3.7, quite large. The environmental demand variables have a uniformly strong effect, only the private water variable has a small effect, while the others range in absolute value between (.74 and 3.09). The income variance variable, an indicator of political weight for the environmental lobby, also has a strong marginal influence with an elasticity of 2.8.

As a group, the environmental demand variables appear to be the strongest influence. It also appears that some variables in the political maximizing category are important in the regulator’s decision making. The results support the common-agency model of regulator behavior, but indicate the regulators put a substantial weight on social welfare as well.

**Conclusion**

The proper design of regulation is only the first stage in ensuring that the goals of regulation are met. Effective enforcement is also necessary. However, comparatively little attention has been focused on the enforcement of regulation. No attention has been paid to how agency decisionmakers prioritize enforcement resources across different policy domains, though many important agencies (such as the FDA, EPA, and SEC) face the precise problem analyzed in this paper: how to allocate scarce resources across several programs.

We develop both normative and positive models of agency program prioritization from utility-theoretic foundations using the common agency approach. The model generates predictions about how agencies will substitute enforcement resources across policy domains in response to pressures from externality-generating and externality-receiving interest groups. The normative model predicts that policy-makers will not be responsive to changes in the homogeneity or concentration of the affected interest groups, while the positive model predicts that policymakers will substitute resources across programs in response to the political mobilization capacity of affected parties. In addition, the results are consistent with the other hypotheses generated by the normative model.

The results suggest that policymakers should take into account local variation in the political market structure when writing regulations. In particular, when regulation is largely decentralized, as in this case, it may be wise for state or national level policymakers to use the results of similar analyses to target resources to jurisdictions that are likely to fall short of regulatory goals due to the strength of a particular interest group.
Bibliography

1253-87.
Discretion. Reinventing government and the problem of bureaucracy. Advances in the Study of
Entrepreneurship, Innovation, and Economic Growth vol. 7. Greenwich, Conn. G.-D. e. Libecap. and
Volume 2: The characteristics of political equilibrium. Elgar Reference Collection series. Aldershot,
U.K, Elgar.
Journal of Economic Literature 38(1): 45-76.
526-36.
765-800.
Environmental Health 52(1): 323-326.
### Tables

1. Variable | Definition
---|---
$c_i$ | Consumption of good $i$.
$\hat{p}_i$ | World price of good $i$.
$T$ | Per capita tax.
$l$ | Per capita labor income.
$\rho_i(p_i)$ | Per-owner profits from good $i$. ($i$ is $x,y$, or $z$)
$x$ | Per-owner production of good $x$.
$y$ | Per-owner production of good $y$.
$\theta_i$ | Pollution intensity of good $i$.
$N_j$ | Number in interest group $j$. ($j$ is environmentalist, owner $x$, owner $y$, or unorganized citizen).
$\bar{X}$ | Total production of $x$.
$\bar{Y}$ | Total production of $y$.
$e_i$ | Regulatory expenditure per unit of good $i$.
$r_i(e_i, \theta_i)$ | Total administrative expenditure on regulation of good $i$.
$p_i = \hat{p}_i - r_i(e_i, \theta_i)$ | Effective price of good $i$ to owner after subtracting marginal cost (to owner) of regulation.
$\varepsilon^x_i$ | % $\Delta x / % \Delta$ in per unit regulatory expenditure on $x$.
$\varepsilon^y_i$ | % $\Delta y / % \Delta$ in per unit regulatory expenditure on $y$. 

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Appendix 2: Proofs of Propositions.

Proof for Proposition ref: pr_pollint: \( \frac{\partial R}{\partial y} > 0 \) and \( \frac{\partial R}{\partial x} < 0 \)

\[
\frac{\partial R}{\partial y} = \frac{[N_E(1 + w\gamma_E)e^\gamma_i + (1 + \gamma_Y)](1 + e^\gamma_i)}{[N_E(1 + w\gamma_E)e^\gamma_i + (1 + \gamma_X)]\theta_x(1 + e^\gamma_i)}
\]

\( (1 + e^\gamma_i) > 0, \theta_x(1 + e^\gamma_i) > 0 \)

Therefore, a sufficient condition for \( \frac{\partial R}{\partial y} > 0 \) is that:

\[
[\frac{N_E(1 + w\gamma_E)e^\gamma_i + (1 + \gamma_Y)]}{[N_E(1 + w\gamma_E)e^\gamma_i + (1 + \gamma_X)]} > 0
\]

This is true if \( [N_E(1 + \gamma_Y)e^\gamma_i + (1 + \gamma_Y)] < 0 \) and \( [N_E(1 + \gamma_X)e^\gamma_i + (1 + \gamma_X)] < 0 \)

This implies:

\[
e^\gamma_i < -\frac{1}{N_E} \frac{(1 + w\gamma_Y)}{(1 + w\gamma_E)} e^\gamma_i < -\frac{1}{N_E} \frac{(1 + w\gamma_x)}{(1 + w\gamma_E)}
\]

The condition for an interior solution (i.e. \( e_y > 0 \)) is:

\[
\theta_x[N_E(1 + w\gamma_E)\theta_x x_p - (1 + w\gamma_x)x] = \lambda(x - \theta_x x_p)
\]

\( \lambda(x - \theta_x x_p) > 0 \) by the assumption that \( \frac{\partial E_x}{\partial e_x} > 0 \), therefore, since \( e_x > 0 \):

\[
\theta_x[N_E(1 + w\gamma_E)\theta_x x_p - (1 + w\gamma_x)x] > 0
\]

solving, this implies:

\[
e^\gamma_i < -\frac{1}{N_E} \frac{(1 + w\gamma_x)}{(1 + w\gamma_E)}
\]

for all interior solutions. The similar inequality for \( y \) can be shown using the same steps.

Therefore, for interior solutions, \( \frac{\partial R}{\partial y} > 0 \). Similar steps show that \( \frac{\partial R}{\partial x} < 0 \)

Q.E.D.

Proof for Proposition ref: pr_indpw: \( \frac{\partial(R)}{\partial\gamma_x} > 0 \), \( \frac{\partial(R)}{\partial\gamma_y} < 0 \)
\[
\frac{\partial R}{\partial \gamma_X} = -w[N_E(1 + w\gamma_E)\varepsilon_t^\gamma + (1 + \gamma_Y)](1 + \varepsilon_t^t) \\
[N_E(1 + w\gamma_E)\varepsilon_t^t + (1 + \gamma_X)]^2 \theta_x(1 + \varepsilon_t^t)
\]

The denominator is positive, and with the same interior solution conditions we can show 
\([N_E(1 + w\gamma_E)\varepsilon_t^\gamma + (1 + \gamma_Y)] < 0\). Therefore, the numerator is positive as well, implying \(\frac{\partial(R)}{\partial \gamma_X} > 0\).

Similar steps can show that \(\frac{\partial(R)}{\partial \gamma_x} > 0\).

**Proof for Proposition ref: pr_envwgt:**

\[R = \frac{t_y}{t_x} = \frac{[N_E(1 + w\gamma_E)\varepsilon_t^\gamma + (1 + w\gamma_Y)]\theta_y(1 + w\varepsilon_t^t)}{[N_E(1 + w\gamma_E)\varepsilon_t^t + (1 + \gamma_X)]\theta_x(1 + w\varepsilon_t^t)}
\]

Let \(\phi_E = N_E(1 + w\gamma_E)\)

\[
\frac{\partial R}{\partial \phi_E} = \frac{\theta_y(1 + \varepsilon_t^t)}{\theta_x(1 + \varepsilon_t^t)} \left[ \frac{\varepsilon_t^\gamma(\phi_E\varepsilon_t^t + 1 + w\gamma_X) - \varepsilon_t^t(\phi_E\varepsilon_t^t + 1 + w\gamma_Y)}{(\phi_E\varepsilon_t^t + 1 + w\gamma_X)^2} \right]
\]

The assumption that increased regulation always increases expenditures implies \((1 + \varepsilon_t^t) > 0\) and \((1 + \varepsilon_t^t) > 0\)

Therefore:

\[
\frac{\theta_y(1 + \varepsilon_t^t)}{\theta_x(1 + \varepsilon_t^t)} \left[ \frac{1}{(\phi_E\varepsilon_t^t + 1 + w\gamma_X)^2} \right] > 0
\]

implying:

\[
\frac{\partial R}{\partial \phi_E} > 0 \text{ if } \varepsilon_t^\gamma > \varepsilon_t^t \frac{1 + w\gamma_Y}{1 + w\gamma_X}
\]

Restating in terms of the absolute value of the elasticities (since the regulation elasticities are both negative):

\[
\frac{\partial R}{\partial \phi_E} > 0 \text{ if } |\varepsilon_t^\gamma| < |\varepsilon_t^t| \frac{1 + w\gamma_Y}{1 + w\gamma_X}
\]

Q.E.D

**Proof for Proposition ref: pr_xenvwgt:**

\[
\frac{\partial R}{\partial \phi_E \partial \theta_y} = \frac{(1 + \varepsilon_t^t)}{\theta_x(1 + \varepsilon_t^t)} \left[ \frac{\varepsilon_t^\gamma(\phi_E\varepsilon_t^t + 1 + w\gamma_X) - \varepsilon_t^t(\phi_E\varepsilon_t^t + 1 + w\gamma_Y)}{(\phi_E\varepsilon_t^t + 1 + w\gamma_X)^2} \right]
\]

Using the same relationships as in the proof of proposition 3, the sign of the right hand side of the equation depends on:
\[ \varepsilon_i^y (\phi_E \varepsilon_i^y + 1 + w \gamma_X) - \varepsilon_i^y (\phi_E \varepsilon_i^y + 1 + w \gamma_Y) \]
determines the sign of \( \frac{\partial R}{\partial \phi_E \partial \theta_y} \) and \( \frac{\partial R}{\partial \phi_E \partial \theta_x} \). Notice this is the same term that determines the sign of \( \frac{\partial R}{\partial \phi_E} \).

Then:

\[ \varepsilon_i^y > \varepsilon_i^x \frac{1 + w \gamma_Y}{1 + w \gamma_X} \Rightarrow \frac{\partial R}{\partial \phi_E} > 0 \quad \text{and} \quad \frac{\partial R}{\partial \phi_E \partial \theta_x} < 0 \]
\[ \varepsilon_i^y < \varepsilon_i^x \frac{1 + w \gamma_Y}{1 + w \gamma_X} \Rightarrow \frac{\partial R}{\partial \phi_E} < 0 \quad \text{and} \quad \frac{\partial R}{\partial \phi_E \partial \theta_x} > 0 \]

Q.E.D.