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The Value of Information in Public Decisions

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Abstract

This paper considers the problem of an imperfectly informed regulator constrained in his choice of environmental regulation by the political opposition of those affected by the policy. We compare the value of two types of information to the regulator: the social cost of pollution and the profitability of firms present in the economy. We find that in environments where small increases in the losses to regulated firms greatly affect the regulator's ability to implement the policy, it is most valuable to learn the types of firms, while it is most valuable to learn the social cost of pollution when small increases in losses are relatively ineffectual.

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1 Introduction

We consider the policy choice of an imperfectly informed regulator constrained by the ability of market participants to block regulation. We then compare the values of two different types of information about market participants to the regulator, the social cost of pollution, and the profitability of firms present in the economy.

Determining when the regulator would prefer learning the social cost of pollution to learning about firm profitability is important for three reasons. First, cost-benefit analysis has long held the status as the fundamental yardstick in policymaking, though perhaps by default. As Richard Posner argues, "My own justification for using cost-benefit analysis... (is based on) ...what I claim to be the inability of judges to get better results using any alternative approach" (Posner, 2000). The Clinton administration institutionalized the use of cost-benefit analysis in public decision making with Executive Order 12866, mandating that agencies "propose or adopt a regulation only upon a reasoned determination that the benefits of the intended regulation justify its costs" (W.J. Clinton, 1993). Consequently, public policy decisions worth billions of dollars are made on the basis of cost-benefit analysis each year. Given this, it is important to assess the extent to which public decisions can be improved by better information. Further, in environments with several sources of uncertainty, determining what type of information to learn is of practical use.

Second, cost-benefit analyses are notoriously inaccurate. One particularly relevant example is the uncertainty surrounding the cost of meeting the Kyoto Protocol targets. In a study comparing the cost estimates from eight different sources, the Energy Information Administration[1] finds significant variance in estimated costs along many dimensions. For example, estimates of annual GDP loss in the United States from meeting the targets range from 91 to 311 billion dollars, while estimated carbon prices range from 147 to 360 1996 dollars per metric ton. Thus, at least seven out of the eight projections are inaccurate to some degree. This wide range for the estimates indicates that there is considerable "noise" present in cost-benefit analysis. By characterizing the value of information we address the question of how much the noise matters, and which type of noise is most worth reducing.

Finally, regulatory agencies generally operate under some budget constraint. Allocating scarce research funding to learning one parameter of the economic environment when learning

[1] Information available at the EIA Kyoto website: http://www.eia.doe.gov/oiaf/kyoto/cost.html

another would yield a higher return can be costly. Our study is intended to improve public decisions by clearly laying out the conditions under which learning costs pays more than learning benefits.

To fix ideas, we consider the specific case of environmental tax policy. Environmental policy is necessarily chosen under uncertainty about both the costs (lost profit to firms) and benefits (reduced pollution) of any particular regulation. Moreover, environmental regulators are often constrained by industry influence on the legislative process, making the probability of implementation a central consideration in the choice of tax. Thus, environmental regulation seems a useful example of our more general problem.

We find that the value of learning costs relative to learning benefits hinges on how politically powerful firms are. We say firms are politically powerful if marginal increases in the tax have disproportionately large effects on the regulator's ability to implement the policy. Our primary finding is that when firms are not politically powerful, information about how costly pollution is to consumer welfare (benefits of regulation) is more valuable than information about the types of firms in the economy (costs of regulation). On the other hand, when firms are politically powerful, it pays more to learn precisely what types of firms are in the economy.

The intuition behind this result is best seen by considering an extreme case. If firms possess no lobbying ability and take any policy as given, all a regulator needs to know to set a first-best tax is how costly pollution is to consumers. However, as firms become increasingly powerful, knowing firm types becomes more important, because the regulator now faces a trade-off: choosing a tax high enough so that *if* it passes the legislative process only efficient firms remain in production, or choosing a regulation that is more likely to pass but that leaves some inefficient firms in the market. Information about firm types helps the regulator make this trade off optimally.

2 Literature Review

The political economy of regulation has its roots in the work of Olson (1964), Stigler (1971) and Becker (1985). Broadly speaking, the contribution of this literature is to offer a convincing theory of "who gets regulated and why". While Olson (1964) frames lobbying by regulated parties as a collective choice problem, it is Stigler (1971) who first developed a theory of the demand for regulation. He argues that the state, which has the unique ability to "prohibit or compel, to take or give money," is largely at the service of well organized groups, a result congruent with Olson's. Becker (1985) formalizes the ideas developed in the earlier papers into a model of strategic competition among pressure (interest) groups for political influence.

This canonical model of regulation largely neglects the role of information and uncertainty. Lewis (1996), the foundation of the present work, remedies this by introducing regulatory uncertainty into the Becker model. Lewis' model incorporates the political constraints of Olson and Becker in the sense that the probability of implementing a policy decreases in the aggregate losses incurred by firms. Lewis also assumes the regulator is unable to observe the type (profitability) of any particular firm in the economy, and shows that in this context a welfare maximizing planner chooses an inefficient policy. Lewis' planner would ideally shut down all socially inefficient firms, but a tax which accomplishes this objective is costly both for firms remaining in the industry and for firms which are forced to shut down. A lower tax, which places a smaller burden on efficient firms, is more likely to be implemented. On the other hand, with a lower tax, some inefficient firms remain in the industry. The optimal (second best) policy is one that does not regulate almost efficient firms but induces very inefficient firms to exit. The optimal policy is inefficient in the sense that, even if the policy survives the legislative process, firms whose profit is smaller than the externality cost they create go unregulated.

Value of Information

The statistical measure of the value of information is the expected value of an informed decision less the expected value of the uninformed decision. To illustrate this idea,[2] consider a risk-neutral gambler who is offered the following gamble: A fair coin will be tossed once. If the gambler predicts the side of the coin that faces up correctly, he wins a dollar, while if the prediction is incorrect, he gets nothing. The gambler can expect to earn 50 cents from the gamble, and so will pay at most fifty cents to play. Now suppose the gambler knows that before making his "prediction", the true outcome of the coin toss will be revealed to him. In this case the gambler expects to earn a dollar from the gamble, because whatever the outcome of the coin toss, he will be able to predict it correctly. In this simple example, the value of information

[2]See Arrow and Fisher (1973) for an early application of the value of information in economics. A more rigorous exposition of the value of information, particularly in the context of irreversibility, is provided in Treixas and Laffont (1985)

is fifty cents: the difference between the expected value of a fully informed decision and the expected value of an uninformed decision.

In the context of our problem, the “gambler” is a welfare maximizing regulator with the option to learn about either the profitability of the firms present in the economy, or the cost they impose on society, before he chooses his policy. We perform calculations analogous to the one above in order to determine when each type of information is more valuable.

3 Model

We want to develop a simple model that incorporates uncertainty into the regulatory setting of Becker (1985). We consider the choice of a lump sum tax by a regulator who is initially uncertain about firms' profits and about the social cost of pollution. The regulator chooses a tax to induce the exit of firms whose profit does not cover the social cost of production. The implementation of the tax is less likely as the losses to firms increase. By deriving the optimal taxes under different information structures we are able to determine what information is most valuable to the regulator in different circumstances.

To be more precise, we consider an economy where heterogeneous firms make a binary decision to either produce or not. Firms that produce earn some profit, and firms that do not earn zero profit. We assume that the firms face perfectly elastic demand. Through productive activity, firms impose a social cost (pollution) on consumers. It is assumed that, whatever this cost is, it is the same for any type of firm. The regulator's proposed policy may be blocked by firms, and the probability of the policy being blocked increases in the losses the tax imposes on firms. We obtain optimal taxes and (expected) social welfare for each possible information set, or ‘type’ of planner, and calculate the statistical values of different types of information.

Formally, the set of firm types in the population is: $\Theta = \{\theta_L, \theta_H\}$, with population frequency $(\alpha, 1-\alpha)$, $\alpha \in [0,1]$. The θ_i's also describe firm profit conditional on entry, with a firm of type θ_i earning profit θ_i gross of any tax. For expositional clarity we suppose that at most two firms may operate in the economy. Let $i \in \{1,2\}$ index the realized set of firms. The sample of realized firms, (θ_1, θ_2), is binomially distributed, with parameters $(2, \alpha)$, with $\alpha \in [0,1]$. That is,

$$\begin{aligned}\text{Prob}\big[(\theta_1,\theta_2)=(\theta_L,\theta_L)\big] &= \alpha^2,\\ \text{Prob}\big[(\theta_1,\theta_2)=(\theta_L,\theta_H)\big] &= \text{Prob}\big[(\theta_1,\theta_2)=(\theta_H,\theta_L)\big]=\alpha(1-\alpha),\\ \text{Prob}\big[(\theta_1,\theta_2)=(\theta_H,\theta_H)\big] &= (1-\alpha)^2.\end{aligned}$$

The social cost of pollution, c, takes one of two values, $\{c_L, c_H\}$, with population frequency $(q, 1-q)$, $q \in [0,1]$. Thus there are six possible states of the world, with representative element $s \in S$. The distribution of probability $\mu(s)$ over the set of states is given in table 1. A planner who learns c will be said to "learn the social cost of pollution", while a planner who learns (θ_1, θ_2) will be said to "learn firm types". This model is among the simplest in which we can sensibly talk about more than one type of information.

Under any proposed policy, firms either pay the tax and remain in production, or exit and pay nothing. The losses firms incur are the sum of profit forgone by firms that exit (those with profit less than the size of the tax), and the taxes paid by firms who remain in production. The firm's stay/exit decision is completely determined by whether profit net of the tax is positive or negative. We assume that indifferent firms exit.

To capture the idea that lobbying makes implementation uncertain we follow Lewis (1996), and suppose that if a tax τ imposes aggregate losses L on firms, the probability of the policy being implemented is *P(L)*, where $P'(L) < 0$ and $P''(L) < 0$. In words, as aggregate losses increase the chances of the policy passing decrease at an increasing rate. From the planner's perspective, Proposed policy is not implemented with certainty, so that choosing a tax is a gamble. The political power of firms depends on the curvature of the $P(\cdot)$ function. If $P(\cdot)$ is steep, small changes in the losses the policy imposes on firms greatly decrease the chances of the policy being implemented. In other words, marginal changes in L are important, and in such a case we say that firms are politically powerful.

We also assume:

$$Ec > \theta_H > c_L \geq \theta_L.$$

$\theta_H > c_L$ means that when the planner draws the sample of firm types and the social cost of pollution, there is strictly positive probability that at least one firm is efficient. $c_L \geq \theta_L$ means that, for whatever social cost the planner has drawn, there is strictly positive probability that the planner has drawn an inefficient firm. First consider the assumption $\theta_H > c_L \geq \theta_L$. These

Table 1: Distribution of probability over states

State s	$Prob(s) \equiv \mu(s)$
$\{\theta_L, \theta_L, c_L\}$	$\alpha^2 q$
$\{\theta_L, \theta_H, c_L\}$	$2\alpha(1-\alpha)q$
$\{\theta_H, \theta_H, c_L\}$	$(1-\alpha)^2 q$
$\{\theta_L, \theta_L, c_H\}$	$\alpha^2(1-q)$
$\{\theta_L, \theta_H, c_H\}$	$2\alpha(1-\alpha)(1-q)$
$\{\theta_H, \theta_H, c_H\}$	$(1-\alpha)^2(1-q)$

two assumptions are not restrictive in the following sense. Suppose that instead of what was presented above, our planner draws the firms from a continuum $\Theta = [\underline{\theta}, \overline{\theta}]$ and social cost from a continuum $C = [\underline{c}, \overline{c}]$. In this alternative framework, as long as $\Theta \cap C \neq \emptyset$ and $\underline{c} \geq \underline{\theta}$, these assumptions hold. The assumption $\theta_H > c_L$ is not necessary for the analysis, but keeps the problem interesting. If it did not hold, production by any type of firm would be inefficient.

The assumption $c_L \geq \theta_L$ is made because, without it, if the planner chooses to learn social cost first and realizes $c = c_L$, he does not wish to set any tax; any firm draw is efficient. Finally, if the assumption $Ec > \theta_H$ didn't hold, a planner informed about firm types that realizes $\{\theta_H, \theta_H\}$ would not want to set a tax regardless of what social cost of pollution he may draw. So the assumptions $c_L \geq \theta_L$ and $Ec > \theta_H$ ensure that, once partial information is obtained there is still a role for regulation.

4 Planner's Problem

The planner's objective is to choose a tax to induce the exit of firms whose profit is no larger than the externality they create. The planner chooses the tax taking into consideration the information he has, and that policies are not implemented with certainty. The planner's welfare criterion does not directly include the loss the tax imposes on firms since the tax is simply a transfer.

Let the function $\mathbf{1}_{\theta_\mathbf{i}}$ indicate that the profit of firm i is greater than the tax τ. That is,

$$\mathbf{1}_{\theta_\mathbf{i}} = \begin{cases} 1 & \text{if } \theta_i > \tau \\ 0 & \text{otherwise.} \end{cases}$$

Then for any given realization $\{\theta_1, \theta_2, c\} \in S$, the payoff to a planner that chooses tax τ is given by:

$$G(\tau, s) = P(L(\tau, s))\big[\mathbf{1}_{\boldsymbol{\theta_1}}(\theta_1 - c) + \mathbf{1}_{\boldsymbol{\theta_2}}(\theta_2 - c)\big] + (1 - P(L(\tau, s)))\big[\sum_i(\theta_i - c)\big]$$

where:

$$L(\tau, s) = \sum_i \Big(\mathbf{1}_{\theta_\mathbf{i}}\tau + (1 - \mathbf{1}_{\theta_\mathbf{i}})\theta_i\Big)$$

At any state s, a fully informed planner or government chooses a tax that solves:

$$\max_{\tau \in \Re} \Big(P(L(\tau, s))\big[\mathbf{1}_{\boldsymbol{\theta_1}}(\theta_1 - c) + \mathbf{1}_{\boldsymbol{\theta_2}}(\theta_2 - c)\big] + (1 - P(L(\tau, s)))\big[\sum_i(\theta_i - c)\big]\Big) \tag{1}$$

Let $\tau_F^*(s)$ denote the optimal *full information* tax in state s, and $G(\tau_F^*(s), s)$ be the planner's payoff. We can write the *expected full information payoff* as:

$$EG_F = \sum_{s \in S} G(\tau_F^*(s), s)\mu(s)$$

In contrast, an uninformed planner chooses a tax independent of the true state of the world. In particular, he chooses a tax to solve:

$$\max_{\tau \in \Re} \sum_{s \in S} \Big(P(L(\tau, s))\big[\mathbf{1}_{\boldsymbol{\theta_1(s)}}(\theta_1(s) - c(s)) + \mathbf{1}_{\boldsymbol{\theta_2(s)}}(\theta_2(s) - c(s))\big] + (1 - P(L(\tau, s)))\big[\sum_i(\theta_i(s) - c(s))\big]\Big)\mu(s) \tag{2}$$

Let τ_U^* denote the optimal *uninformed* tax, and $G(\tau_U^*, s)$ be the planner's payoff to choosing this tax when the true state is s. Note that here the planner may choose only one tax regardless of what the true state is, as information about the state will not be revealed to him. We can thus write the *expected uninformed payoff* as:

$$EG_U = \sum_{s \in S} G(\tau_U^*, s)\mu(s)$$

To calculate the value of learning the social cost of pollution or firm type (but not both), we must state the partially informed planner's problem.

To describe how new data changes the planner's beliefs, it is convenient to use the concept of information "partitions" . Formally, a partition of the sample space S is a collection of subsets, or events, $A_1, ..., A_n$ such that $\cup_{i=1}^n A_i = S$ and $\cap_{i=1}^n A_i = \emptyset$. A partition groups

Table 2: Information partition Ω_θ induced by information about firms

Event ω_θ	Probability $\mu(\omega_\theta)$
$\{\{\theta_L, \theta_L, c_L\}, \{\theta_L, \theta_L, c_H\}\}$	α^2
$\{\{\theta_L, \theta_H, c_L\}, \{\theta_L, \theta_H, c_H\}\}$	$2\alpha(1-\alpha)$
$\{\{\theta_H, \theta_H, c_L\}, \{\theta_H, \theta_H, c_H\}\}$	$(1-\alpha)^2$

realizations $\{\theta_1, \theta_2, c\}$ together, and allows a planner to distinguish across, but not within groups of realizations.

Letting Ω_θ represent the partition and ω_θ an event in the partition, the elements of the partition and their population frequencies are given in table 2. Information about firm types partitions the set of states into three disjoint sets, which the planner can distinguish from one another. Each of these sets contains two elements, between which the planner is unable to distinguish. In words, when the planner learns firm types he learns whether he faces two low type firms, two high types, or one of each type. However, he does not learn whether social cost of pollution is high or low.

A planner who learns the types of firms but is uncertain of the social cost has expected payoff,

$$\max_{\tau \in \Re} \sum_{s \in \omega_\theta} \Big(P(L)\big[\mathbf{1}_{\boldsymbol{\theta_1}}(\theta_1 - c(s)) + \mathbf{1}_{\boldsymbol{\theta_2}}(\theta_2 - c(s))\big] + (1 - P(L))\big[\sum_i (\theta_i - c(s))\big]\Big)\mu(s|s \in \omega_\theta). \quad (3)$$

Here the planner does not know the realization $\{\theta_1, \theta_2, c\}$ exactly, but he knows that the realization falls in the set ω_θ. As before, for whichever state s that the planner realizes and tax τ he chooses, the payoff $G(\tau, s)$ is obtained. The planner thus chooses a tax τ to maximize the expected value of $G(\tau, s)$, given that $s \in \omega_\theta$. Let $\tau^*_{\Omega_\theta}(\omega_\theta)$ be the solution to this problem, the optimal tax under partial information about firm types. This tax balances the benefit of shutting down socially inefficient firms against the cost of reducing the probability of implementation.

We can write the *expected partial information payoff* from learning firm types as,

$$EG_{\Omega_\theta} = \sum_{\omega_\theta \in \Omega_\theta} \sum_{s \in \omega_\theta} G(\tau^*_{\Omega_\theta}(\omega_\theta), s)\mu(s|s \in \omega_\theta)\mu(\omega_\theta).$$

In words, a planner anticipating information about firm types forms an expectation over the the information he could receive (the elements ω_θ of the partition Ω_θ), knowing that once he obtains

Table 3: Information partition Ω_c induced by cost information

Event ω_c	Probability $\mu(\omega_c)$
$\{\{\theta_L, \theta_L, c_L\}, \{\theta_L, \theta_H, c_L\}, \{\theta_H, \theta_H, c_L\}\}$	q
$\{\{\theta_L, \theta_L, c_H\}, \{\theta_L, \theta_H, c_H\}, \{\theta_H, \theta_H, c_H\}\}$	$1-q$

this information he will choose the tax that maximizes expected social welfare conditional on his information. Note that this partially informed problem is intermediate between that which the planner faces when fully informed and uninformed. In (3) the planner can choose one of three taxes, one for each element of the partition. This contrasts with the fully informed and uninformed planner's problem, where the planner chooses six taxes and one tax respectively.

When the planner learns social cost of pollution but not firm types, he learns whether the cost of pollution is high or low, but not the types of firms that are present. Formally, information about social cost of pollution c partitions the set of states of the world into two disjoint sets between which the planner can distinguish. Each set contains three elements, between which the planner can not distinguish. Letting Ω_c represent this partition and ω_c an event in Ω_c, table 3 gives the elements of the partition and their population frequencies.

We can now write the partial information payoffs when the planner learns the social cost of pollution but not firm types,

$$\max_{\tau \in \Re} \sum_{s \in \omega_c} \Big(P(L(\tau, s)) \big[\mathbf{1}_{\boldsymbol{\theta_1}(\mathbf{s})}(\theta_1(s) - c) + \mathbf{1}_{\boldsymbol{\theta_2}(\mathbf{s})}(\theta_2(s) - c) \big] + (1 - P(L(\tau, s))) \big[\sum_i (\theta_i(s) - c) \big] \Big) \mu(s | s \in \omega_c).$$

Letting $\tau_c^*(\omega_c)$ denote the optimal tax under partial information about social cost given the information ω_c, the expected partial information payoff is:

$$EG_{\Omega_c} = \sum_{\omega_c \in \Omega_c} \sum_{s \in \omega_c} G(\tau_c^*(\omega_c), s) \mu(s | s \in \omega_c) \mu(\omega_c).$$

5 Optimal taxes

To calculate the value of the three types of information, we need to obtain the tax that maximizes social welfare for a planner with each possible type of information: a fully informed planner, either type of partially informed planner, and an uninformed planner. We can then characterize and compare the values of the different types of information.

We first observe that a welfare-maximizing planner may restrict himself to choosing a tax from $\{\theta_L, \theta_H\}$ without loss. That is, any type of planner can ignore taxes outside the set $\{\theta_L, \theta_H\}$ when choosing the optimal tax. To see this, note first that a planner is indifferent between taxes $\tau = \theta_H$ and $\tau \in (\theta_H, \infty)$. The former leaves a high type firm with zero profit, and we have assumed that firms exit when they earn zero profit, while the latter set of taxes clearly induces shut-down. Both types of firm exit for any $\tau \in [\theta_H, \infty)$, and aggregate losses are constant over $[\theta_H, \infty)$. Notice as well that, as we have assumed $c_L \geq \theta_L$, a tax of $\tau = \theta_L$ is strictly preferred by the planner to any tax $\tau < \theta_L$. Under the latter, no firms exit when the policy is passed, while under the former low-types exit, and a planner would always like to induce low firms to exit. Together these imply that, without any loss in generality, we need only consider taxes $\tau^* \in [\theta_L, \theta_H]$.

It only remains to show that the optimal tax may not lie in the open interval (θ_L, θ_H). Suppose to the contrary that $\tau^* \in (\theta_L, \theta_H)$. By decreasing the tax by $\varepsilon \in (0, \tau^* - \theta_L)$, the planner reduces the loss directly incurred by firms while leaving firm exit decisions unchanged. But if this is true, then the planner has increased the probability of implementing the tax policy without changing expected welfare, contradicting the optimality of τ^*. Therefore the only taxes we need consider are in the set $\{\theta_L, \theta_H\}$.

We can now calculate the optimal tax in each of the six possible states in S. Letting $\tau_F^*(s)$ denote the optimal *full information* tax in state s, the optimal taxes are given in table 4.

Given the realization $\{\theta_L, \theta_L, c_L\}$, the planner is indifferent between any taxes that induce low types to exit the market. Any tax at least as large as θ_L induces low type firms to exit, and losses incurred by the low type firms do not increase once tax exceeds θ_L. As we can always restrict ourselves to the set $\{\theta_L, \theta_H\}$ when looking for the optimal tax, this completes the argument. The same argument applies to the realization $\{\theta_L, \theta_L, c_H\}$.

Now consider $\{\theta_L, \theta_H, c_L\}$. In this state the planner optimally shuts down the low-type and leaves the high type unregulated. A tax of θ_L uniquely solves this problem. In the case of $\{\theta_H, \theta_H, c_L\}$ the planner would prefer to leave both firms unregulated. Under a tax of θ_L neither firm exits.[3] For the realization $\{\theta_H, \theta_H, c_H\}$ the planner optimally shuts down both

[3]Note that for the social welfare criterion we use, the planner does not care whether or not regulation is

Table 4: Optimal taxes in each possible state

State s	Optimal Tax $\tau_F^*(s)$
$\{\theta_L, \theta_L, c_L\}$	$\{\theta_L, \theta_H\}$
$\{\theta_L, \theta_H, c_L\}$	θ_L
$\{\theta_H, \theta_H, c_L\}$	θ_L
$\{\theta_L, \theta_L, c_H\}$	$\{\theta_L, \theta_H\}$
$\{\theta_L, \theta_H, c_H\}$	$\begin{cases} \theta_L & \text{if } \frac{(\theta_H - c_H)+(\theta_L - c_H)}{(\theta_L - c_H)} \leq \frac{P(2\theta_L)}{P(\theta_H+\theta_L)} \\ \theta_H & \text{if } \frac{(\theta_H - c_H)+(\theta_L - c_H)}{(\theta_L - c_H)} > \frac{P(2\theta_L)}{P(\theta_H+\theta_L)} \end{cases}$
$\{\theta_H, \theta_H, c_H\}$	θ_H

Table 5: Optimal taxes when the planner knows firm types only

Event ω_θ	Optimal Tax $\tau_\theta^*(\omega_\theta)$
$\{\{\theta_L, \theta_L, c_L\}, \{\theta_L, \theta_L, c_H\}\}$	$\{\theta_L, \theta_H\}$
$\{\{\theta_L, \theta_H, c_L\}, \{\theta_L, \theta_H, c_H\}\}$	$\begin{cases} \theta_L & \text{if } \frac{(\theta_H - Ec+(\theta_L - Ec)}{(\theta_L - Ec)} \leq \frac{P(2\theta_L)}{P(\theta_H+\theta_L)} \\ \theta_H & \text{if } \frac{(\theta_H - Ec)+(\theta_L - Ec)}{(\theta_L - Ec)} > \frac{P(2\theta_L)}{P(\theta_H+\theta_L)} \end{cases}$
$\{\{\theta_H, \theta_H, c_L\}, \{\theta_H, \theta_H, c_H\}\}$	θ_H

firms, which any tax at least as large as θ_H does.

Finally, consider $\{\theta_L, \theta_H, c_H\}$. In this case the planner faces a trade-off. On the one hand, both of the firms are inefficient, and the planner would ideally shut down both of them, which in turn requires a high tax, $\tau = \theta_H$. However, while a high tax may shut down both firms, such a tax imposes larger losses on firms and is less likely to be enacted than a low tax that shuts down only the most inefficient firm θ_L. This is the essence of the lobbying problem the planner faces. The optimal tax can be θ_L or θ_H depending on the importance of lobbying.

We now turn attention to the calculation of optimal taxes when the planner learns firm types but not the social cost of pollution. Optimal taxes for each element of the relevant partition are given in table 5.

When $\{\{\theta_L, \theta_L, c_L\}, \{\theta_L, \theta_L, c_H\}\}$ is realized, whatever the social cost of pollution, both firms are inefficient. Any tax at least as large as θ_L induces the firms to exit, and all such taxes

enacted in this case.

Table 6: Optimal taxes when social cost is known

Event ω_c	Optimal tax $\tau_c^*(\omega_c)$
$\{\{\theta_L,\theta_L,c_L\},\{\theta_L,\theta_H,c_L\},\{\theta_H,\theta_H,c_L\}\}$	θ_L
$\{\{\theta_L,\theta_L,c_H\},\{\theta_L,\theta_H,c_H\},\{\theta_H,\theta_H,c_H\}\}$	$\begin{cases}\theta_L & \text{if } \frac{P(2\theta_L)(\theta_L-c_H)-P(\theta_H+\theta_L)[(\theta_H-c_H)+(\theta_L-c_H)]}{P(2\theta_H)[\theta_H-c_H]} > \frac{1-\alpha}{\alpha}\\ \theta_H & \text{if } \frac{P(2\theta_L)(\theta_L-c_H)-P(\theta_H+\theta_L)[(\theta_H-c_H)+(\theta_L-c_H)]}{P(2\theta_H)[\theta_H-c_H]} \leq \frac{1-\alpha}{\alpha}\end{cases}$

impose equal losses on the firms. Thus the optimal tax is θ_L.

When $\{\{\theta_L,\theta_H,c_L\},\{\theta_L,\theta_H,c_H\}\}$, is realized the planner faces a trade-off similar to that when he is fully informed and the state of the world is given by $\{\theta_L,\theta_H,c_H\}\}$. We have assumed that $Ec > \theta_H$ so both firms are inefficient in expectation. From the point of view of expected efficiency a high tax is strictly optimal. However, high taxes are less likely to be implemented than low taxes, and thus the preferred tax hinges on the relative inefficiencies of the two types of firms. The more inefficient the low type is relative to the high type, or equivalently, the faster the probability of implementation decreases in losses, the greater the planner's inclination to choose a low tax.

Last, when the realization is $\{\{\theta_H,\theta_H,c_L\},\{\theta_H,\theta_H,c_H\}\}$, both firms are inefficient in expectation. Given the planner's information it is optimal to regulate both firms and thus a high tax is chosen.

We now calculate optimal taxes under the assumption that the planner knows the social cost but not firm types. The optimal taxes under the partition induced by this information are given in table 6.

When costs are low, i.e., $\{\{\theta_L,\theta_L,c_L\},\{\theta_L,\theta_H,c_L\},\{\theta_H,\theta_H,c_L\}\}$ is realized, only the low type is inefficient. A low tax is uniquely optimal since a high tax shuts down efficient firms.

When costs are high, $\{\{\theta_L,\theta_L,c_H\},\{\theta_L,\theta_H,c_H\},\{\theta_H,\theta_H,c_H\}\}$ is realized. If the planner knew that the true state was an element of $\{\{\theta_L,\theta_L,c_H\},\{\theta_H,\theta_H,c_H\}\}$ the optimal policy would clearly be a high tax. That the planner can not distinguish between these states and $\{\theta_L,\theta_H,c_H\}$ complicates matters, because the fact that $\{\theta_L,\theta_H,c_H\}$ is possible forces the planner to weigh the net benefit of a low tax against the net benefit of a high tax. The planner must choose between a higher probability of implementation at the cost of efficiency, and more efficiency at the cost of lower probability of implementation. If, conditional on the true state being an element of $\{\{\theta_L,\theta_L,c_H\},\{\theta_H,\theta_H,c_H\}\}$, the likelihood of drawing the realization $\{\theta_L,\theta_H,c_H\}$

is sufficiently high, and the probability of implementation decreases quickly enough as losses increase, the planner will prefer a low tax to a high one.

Finally, we derive the uninformed planner's optimal tax. This tax is given by:

$$\tau_U^* = \begin{cases} \theta_L & \text{if } \frac{P(2\theta_L)(\theta_L - Ec) - P(\theta_H+\theta_L)[(\theta_H - Ec)+(\theta_L - Ec)]}{P(2\theta_H)(\theta_H - Ec)} > \frac{1-\alpha}{\alpha} \\ \theta_H & \text{otherwise.} \end{cases}$$

Recalling that an uninformed planner must trade-off probability of implementation with efficiency, this condition says that when marginal changes in political resistance are important, an uninformed planner chooses a low tax, and when marginal changes are not so important he chooses a high tax. Of course the relative frequencies of firm types and social cost play a role as well. For example if the probability of drawing a high type firm is sufficiently large relative to the probability of drawing a low type firm (i.e., $\alpha \to 0$) it is easy to see from the above expression that a high tax is optimal.

6 The Value of Information

In this section we use the optimal taxes derived above to determine which information is more valuable to the planner, and when.

By definition, the value of learning firm types is given by,

$$V_{\Omega_\theta} = EG_{\Omega_\theta} - EG_U,$$

while the value of learning social cost of pollution is,

$$V_{\Omega_c} = EG_{\Omega_c} - EG_U.$$

With this notation in place, we can state our first proposition.

Proposition 1

1. *The value of learning the types of firms, V_{Ω_θ}, is zero if firms' political power is sufficiently small. Formally:*

$$\textit{If} \quad P(2\theta_L)(\theta_L - Ec) \geq P(\theta_H + \theta_L)[(\theta_L - Ec) + (\theta_H - Ec)] \quad \textit{then} \quad V_\theta = 0.$$

2. *The value of learning social cost of pollution, V_{Ω_c}, is zero if the firms' political power is sufficiently large. Formally:*

$$\text{If} \quad P(2\theta_L)(\theta_L - c_H) \leq P(\theta_H + \theta_L)[(\theta_L - c_H) + (\theta_H - c_H)] + \frac{1-\alpha}{\alpha} P(2\theta_H)(\theta_H - c_H) \quad \text{then} \quad V_c = 0.$$

Beginning with proposition 1.1, consider an uninformed planner who optimally taxes τ_U^*. Suppose that once the planner learns the firm types but not social cost of pollution, the tax τ_U^* remains optimal for any possible pair of firm types. That is $\tau_U^* = \tau_\theta^*(\omega_\theta)$ for all $\omega_\theta \in \Omega_\theta$. Then, in an ex-ante sense the planner receives the same expected payoff whether he is informed about firm types or has no information at all. For parameter values such that this is true, information about firm types can not have value. Proposition 1 provides conditions under which the planner's optimal tax with and without information are the same. When this is the case, information has no value.

To see when the value of information about firm types can be zero, let us first determine when it is strictly positive. Suppose first that the planner only regulates the low type firm when uninformed: $\tau_U^* = \theta_L$. Looking at table 5, if $\omega_\theta = (\{\theta_H, \theta_H, c_L\}, \{\theta_H, \theta_H, c_H\})$ is realized, that is, the planner learns that the sample contains two high types, the optimal tax decision is $\tau^*(\omega_\theta) = \theta_H$. Thus, with probability $(1-\alpha)^2$ information about firm types changes the optimal tax decision when the optimal uninformed tax is low, and in this case learning the sample must be of value.

Now suppose an uninformed planner optimally chooses: $\tau_U^* = \theta_H$. Then, again looking at table 5, if either

$$\omega_\theta = (\{\theta_L, \theta_L, c_L\}, \{\theta_L, \theta_L, c_H\}),$$

or

$$\omega_\theta = (\{\theta_H, \theta_H, c_L\}, \{\theta_H, \theta_H, c_H\})$$

is realized, then $\tau_U^* = \theta_H$ remains optimal. In the first case the planner is indifferent over all taxes that induce low types to exit, and in the second case, since $Ec > \theta_H$ the planner prefers a high tax. However, if the realization is $(\{\theta_L, \theta_H, c_L\}, \{\theta_L, \theta_H, c_H\})$, the optimal tax may be high or low, depending on how quickly $P(\cdot)$ decreases. If $P(\cdot)$ decreases quickly, then going from a low tax to a high tax can drastically reduce the probability of implementing the policy, while if $P(\cdot)$ does not decrease quickly the optimal tax under this realization is high. If the latter is true, then for any possible realization of firm types the planner prefers a high tax. If he also optimally chooses a high tax when he has no information, then information about firm types can not have value, because it does not change the optimal tax. The above argument is exactly summarized by the inequality in proposition 1.1, which simply says that a planner who realizes $\{\{\theta_H, \theta_L\}, c\}$ prefers a high tax.

Example: Consider the parameterization,

$$P(L) = 1 - \frac{1}{B} L^2,$$

where $B \in [(2\theta_H)^2, \infty)$ so that $P(L)$ is a proper probability distribution. This choice for the function $P(L)$ provides a convenient way to consider comparative statics with respect to political power. Note that

$$P'(L) = -\frac{2L}{B}, \quad P''(L) = -\frac{2}{B}$$

As we noted above, the political power of firms as we have defined it here, depends on the curvature of the $P(\cdot)$ function. If marginal changes in L are important we say that firms are politically powerful. Changing the parameter B allows us to change how important marginal changes in L are, holding all else fixed. The way we have set up this example, small values of B correspond to high political power, while larger values of B correspond to low political power. Now, under this parameterization, proposition 1.1 says that the value of learning firm types is zero if:

$$\left(1 - \frac{1}{B}(2\theta_L)^2\right)(\theta_L - Ec) \geq \left(1 - \frac{1}{B}(\theta_L + \theta_H)^2\right)\left[(\theta_L - Ec) + (\theta_H - Ec)\right]$$

which, after rearranging yields:

$$\frac{\left(1 - \frac{1}{B}(2\theta_L)^2\right)}{\left(1 - \frac{1}{B}(\theta_L + \theta_H)^2\right)} \leq 1 + \frac{\theta_H - Ec}{\theta_L - Ec}.$$

Note that the right hand side of this expression is greater than 1 by our assumption $Ec > \theta_H$. Then, as B gets large,

$$\frac{\left(1 - \frac{1}{B}(2\theta_L)^2\right)}{\left(1 - \frac{1}{B}(\theta_L + \theta_H)^2\right)} \to 1 < 1 + \frac{\theta_H - Ec}{\theta_L - Ec}$$

In words, as the slope of $P(L)$ gets very flat so that marginal changes in L leave the probability of implementation unaffected, the inequality holds with certainty and the value of learning firm types is zero. On the other hand, it is straightforward to find parameter values for which the inequality does not hold. If $\theta_L \approx 0$ and $\theta_H \approx Ec$, the left hand side becomes 4/3 while the right hand side becomes 1. □

To understand proposition 1.2, note that information about social cost can only have zero value if the planner chooses the same tax for any value of social cost he draws. Note that information about social cost has value if $\tau_U^* = \theta_H$. This is true because when social cost is low the optimal tax is $\tau^* = \theta_L$ for any possible sample. Thus information about social cost changes the planner's tax choice with positive probability (probability q). So for information about social cost to have no value, the planner must optimally regulate only the low type for any realization of social cost. In other words, the planner must tax low even in the event $c = c_H$. For this to be true, lobbying must be very important. Indeed, the inequality in proposition 1.2 says that when the planner does not know firm types but knows that social cost is high, he prefers a low tax.

Example cont'd Continuing with the parameterization given above, proposition 1.2 says that the value of learning the social cost of pollution is zero if:

$$\left(1-\frac{1}{B}(2\theta_L)^2\right)(\theta_L-c_H) \leq \left(1-\frac{1}{B}(\theta_L+\theta_H)^2\right)\left[(\theta_L-c_H)+(\theta_H-c_h)\right]+\frac{1-\alpha}{\alpha}\left(1-\frac{1}{B}(2\theta_H)^2\right)(\theta_H-c_H)$$

First, letting B gets large we have:

$$\begin{aligned} \left(1-\frac{1}{B}(2\theta_L)^2\right)(\theta_L-c_H) &\rightarrow \theta_L-c_H \\ \left(1-\frac{1}{B}(\theta_L+\theta_H)^2\right)\left[(\theta_L-c_H)+(\theta_H-c_h)\right] &\rightarrow (\theta_L-c_H)+(\theta_H-c_H) \\ \frac{1-\alpha}{\alpha}\left(1-\frac{1}{B}(2\theta_H)^2\right)(\theta_H-c_H) &\rightarrow \frac{1-\alpha}{\alpha}(\theta_H-c_H) \end{aligned}$$

and the inequality thus approaches:

$$0 \leq \theta_H - c_H$$

and as we have assumed $\theta_H < c_H$, the inequality does not hold. This is indeed consistent with proposition 1.2, as it shows that when firm political power becomes arbitrarily small the value of learning social cost of pollution can not be zero. Now, letting B approach its lower bound,

$(2\theta_H)^2$ we have:

$$\begin{aligned} \Big(1 - \frac{1}{B}(2\theta_L)^2\Big)(\theta_L - c_H) &\rightarrow \Big(1 - \frac{(2\theta_L)^2}{(2\theta_H)^2}\Big)(\theta_L - c_H) \\ \Big(1 - \frac{1}{B}(\theta_L + \theta_H)^2\Big)\big[(\theta_L - c_H) + (\theta_H - c_h)\big] &\rightarrow \Big(1 - \frac{(\theta_L + \theta_H)^2}{(2\theta_H)^2}\Big)\big[(\theta_L - c_H) + (\theta_H - c_H)\big] \\ \frac{1-\alpha}{\alpha}\Big(1 - \frac{1}{B}(2\theta_H)^2\Big)(\theta_H - c_H) &\rightarrow 0 \end{aligned}$$

In this case, the inequality reduces to

$$\Big(1 - \frac{(2\theta_L)^2}{(2\theta_H)^2}\Big)(\theta_L - c_H) \leq \Big(1 - \frac{(\theta_L + \theta_H)^2}{(2\theta_H)^2}\Big)\big[(\theta_L - c_H) + (\theta_H - c_H)\big]$$

This inequality holds for certain parameter values. One example of where it does hold is when $\theta_L \approx 0$ and $\theta_H \approx c_H$. $\square$

Proposition 2

1. *Learning the social cost of pollution yields the expected full information payoff if firms' political power is sufficiently small. Formally:*

$$\textit{If} \quad p(2\theta_L)(\theta_L - c_H) \geq p(\theta_H + \theta_L)[(\theta_L - c_H) + (\theta_H - c_H)] \quad \textit{then} \quad V_c = V_F.$$

2. *Learning only the types of firms never yields the expected full information payoff. That is,*

$$V_\theta < V_F.$$

For information about social cost of pollution to yield the full information payoff, learning firm types once social cost is known must not change the planner's tax choice in any state of the world. Similarly, for information about firm types to yield the full information payoff, learning social cost once firm types are known must not change the planner's tax choice in any state of the world. Let us first establish that learning firm types can never yield the full information payoff. To see this, note that if the planner learns that both firms are high types, i.e., $\{(\theta_H, \theta_H, c_L), (\theta_H, \theta_H, c_H)\}$ is realized, the planner would strictly prefer to leave the firms unregulated if the true social cost of pollution is c_L, but would optimally regulate them if true social cost of pollution is c_H. So in an ex-ante sense, regardless of the parameter values, learning θ does not yield the full information payoff. The planner knows that there is positive probability of drawing a sample of firm types such that it will still pay to learn social cost.

Learning social cost of pollution can yield the full information payoff, however. To see this, note first that the optimal tax does not vary across the states $\{\theta_L, \theta_L, c_L\}, \{\theta_L, \theta_H, c_L\}, \{\theta_H, \theta_H, c_L\}$; once the planner observes that social cost of pollution is low, regardless of what the types of firms are, a low tax is optimal. Now suppose that $c = c_H$. The three possible states of the world are then:

$$\{\theta_L, \theta_L, c_H\}, \{\theta_L, \theta_H, c_H\}, \{\theta_H, \theta_H, c_H\}$$

In the first and last case a high tax is optimal. However, for a mixed sample the level of the tax depends on how quickly $P(\cdot)$ decreases, or how likely the policy is to pass. If lobbying is not important, the planner would choose to regulate both firms, and set a high tax. If this is true, then there is a unique optimal tax across all possible firm pairs for each possible level of social cost, and learning c yields the full information payoff.

Example cont'd After some re-arranging, under the parameterization above proposition 2.1 says that learning social cost yields the full information payoff when:

$$\frac{\left(1 - \frac{1}{B}(2\theta_L)^2\right)}{\left(1 - \frac{1}{B}(\theta_L + \theta_H)^2\right)} \leq 1 + \frac{\theta_H - c_H}{\theta_L - c_H}.$$

Clearly, as B becomes arbitrarily large the inequality holds. In words, as the function $P(L)$ becomes arbitrarily flat and marginal changes in L do not affect the probability of implementation, learning the social cost of pollution yields the full information payoff. □

Corollary: Marginal value of information

1. *Learning firm types after social cost is known is of no value if firm political power is sufficiently small.*

2. *Information about social cost always has value when firm types are known.*

The "marginal" values of information, (i.e., what the planner would pay to learn social cost of pollution after information about firm types has been obtained, and vice versa) also depends on how important lobbying is. When firms possess significant political power, both marginal values are strictly positive. This is the same as saying that when lobbying is very important, learning only one type of information is not enough for a first-best solution. When lobbying is not important, it is always worthwhile to learn c after learning firm types, but it may be of no value to learn the sample after learning c.

Whether or not the marginal value to either type of information is positive follows immediately from our discussion about whether partial information can yield the expected full information payoff. We noted that once the types of firms have been observed the planner is always willing to pay for information about the social cost of pollution. Thus the marginal value of information is always positive in this case. We also noted that if lobbying is not important, information about social cost of pollution yields the expected full information payoff, and thus the marginal value of information is zero. However if lobbying is important, partial information about social cost can't yield the expected full information payoff, and the marginal value of information is positive.

7 Conclusion

We model an economy where a regulator chooses optimal environmental regulation in the presence of political constraints and hidden information. We use the model to compare the relative values of information about the social cost of pollution and the types of firms present in the economy. We find that in environments where firms are politically powerful, it pays a regulator most to learn the types of firms. On the other hand, when firms are not politically powerful, it pays most to learn the social cost of pollution. While we present our results using a deliberately simple model, this intuition is general. Indeed, the main results appear to generalize to an environment with many firm types and levels of social costs.

The relative values of information hinge on the political power of firms because, when the probability of implementing a policy is not sensitive to the losses that firms incur as a consequence of the policy, choosing the optimal regulation amounts to setting the tax to equal the externality (pollution) cost of production. This is the first best tax, and so information about social cost of pollution is much more valuable to this end than is information about firm types. On the other hand, when a high tax is much less likely to be implemented than a low tax, a welfare-maximizing planner would treat a sample of high profit, inefficient firms differently from a mixed sample of high and low profit inefficient firms. In the latter case there is more surplus at stake from not passing the policy. Information about firm types is more valuable in this instance. To say this another way, information about firm types allows the regulator to choose regulation that affects only firms that are less able to influence the political process. In an environment where marginal changes in political resistance are important, this means that information about firm type can be very valuable. If marginal changes in political resistance are not important, information that leads to the first best, i.e., information about social cost, is more valuable.

Relaxing the assumption of binary production choice and allowing firms to choose quantity in the context of the model we present here comes at great cost in terms of tractability and clarity, and generates small benefit in intuition over and above the propositions we have discussed here. Finding the correct way to extend the model in this direction without losing the simplicity inherent to the binary setup remains a subject for future research.

Given the results we have obtained here, the conclusions of Olson (1982), Becker (1985) and Stigler (1971) suggest that when a regulator is facing a concentrated industry he would do well to learn firm types as opposed to the true social cost of pollution, as concentrated industries are conducive to firm mobilization. In other words, the probability of implementing policy is a concern and lobbying is important. When lobbying is important, being able to distinguish what types of firms the planner is facing is relatively valuable. This allows the planner to infer the probability of implementing policy more precisely. On the other hand, if the regulator finds himself in an industry with many small firms that can not organize effectively, learning the social cost of pollution is preferable, because the benefit from getting the tax closer to the actual cost of pollution outweighs the cost from potentially not implementing the tax.

8 Appendix

Proof of Proposition 1

Proposition 1 asserts that under some conditions on the parameters the value to either type of information is zero. To prove this result, we need only show that when these conditions hold, the uninformed planner's optimal tax choice is the same as the tax choice of a planner that has the information in question. We prove each of of proposition 1.1 and 1.2 in turn.

First we show that:

$$p(2\theta_L)(\theta_L - Ec) \geq p(\theta_H + \theta_L)[(\theta_L - Ec) + (\theta_H - Ec)] \Rightarrow V_\theta = 0.$$

Note first that if the parameters satisfy:

$$p(2\theta_L)(\theta_L - Ec) \geq p(\theta_H + \theta_L)[(\theta_L - Ec) + (\theta_H - Ec)],$$

then looking at Table 5, for the realization $\{\{\theta_L, \theta_H, c_L\}, \{\theta_L, \theta_H, c_H\}\}$ the planner prefers a high tax. This then implies that a high tax is optimal for any of the three samples that are possible when the planner gains information about firm types. Further,

$$\begin{aligned} p(2\theta_L)(\theta_L - Ec) &\geq p(\theta_H + \theta_L)[(\theta_L - Ec) + (\theta_H - Ec)] \\ \Rightarrow p(2\theta_L)(\theta_L - Ec) &\geq p(\theta_H + \theta_L)[(\theta_H - Ec) + (\theta_L - Ec)] + \frac{1-\alpha}{\alpha} p(2\theta_H)(\theta_H - Ec), \end{aligned}$$

which implies that the planner prefers a high tax with no information. Altogether, the planner prefers a high tax with no information, and chooses a high tax for any of the three possible realizations when he gains information about firm types. There can not be a value to learning firm types.

Now we show that:

$$p(2\theta_L)(\theta_L - c_H) \leq p(\theta_H + \theta_L)[(\theta_L - c_H) + (\theta_H - c_H)] + \frac{1-\alpha}{\alpha} p(2\theta_H)(\theta_H - c_H) \Rightarrow V_c = 0$$

First, from table 6, if

$$p(2\theta_L)(\theta_L - c_H) \leq p(\theta_H + \theta_L)[(\theta_L - c_H) + (\theta_H - c_H)] + \frac{1-\alpha}{\alpha} p(2\theta_H)(\theta_H - c_H)$$

then the planner chooses a low tax even when the social cost is high. Then, for either realization of social cost, the optimal tax is low.

Further,

$$\begin{aligned} p(2\theta_L)(\theta_L - c_H) &\leq p(\theta_H + \theta_L)[(\theta_L - c_H) + (\theta_H - c_H)] + \frac{1-\alpha}{\alpha} p(2\theta_H)(\theta_H - c_H) \\ \Rightarrow p(2\theta_L)(\theta_L - Ec) &\leq p(\theta_H + \theta_L)[(\theta_H - Ec) + (\theta_L - Ec)] + \frac{1-\alpha}{\alpha} p(2\theta_H)(\theta_H - Ec) \end{aligned}$$

and thus an uninformed planner optimally taxes low. Altogether, a planner taxes low for either realization when information about social cost is gained, but taxes low when he has no information anyways. The value of learning social cost can't be positive. □

Proof of Proposition 2

Proposition 2.1 establishes conditions under which learning only the social cost of pollution leaves the planner as well off as if he would be with full information. To prove this we need to show that, for each possible level of social cost, once information about social cost is obtained, learning the types of firms would not change the planner's choice of tax.

Now suppose

$$p(2\theta_L)(\theta_L - c_H) \geq p(\theta_H + \theta_L)[(\theta_L - c_H) + (\theta_H - c_H)]$$

Note that (see table 4) if the parameter values satisfy this condition a fully informed planner regulates both types for the realization $\{\theta_L, \theta_H, c_H\}$. This implies that a high tax is always optimal when $c = c_H$, regardless of firm types. Further, we know that if $c = c_L$ a low tax is always optimal. Thus once the planner knows the social cost, learning firm types does not change his choice of tax regardless of the types, and thus does not change his ex-post payoff. Information about social cost yields the full information payoff.

We now prove proposition 2.1, that information about firm types can never yield the full information payoff:

$$V_\theta \neq V_F$$

To prove this, we need find only one possible realization of firm types such that learning social cost in addition to information about firm types changes the planner's tax choice. If we can find such a case, information about firm types can't yield full information payoff, because the planner's ex-post payoff can change with more information. So consider the realization

$$\{\{\theta_H, \theta_H, c_L\}, \{\theta_H, \theta_H, c_H\}\}$$

In this case, without further information the planner chooses a high tax, as both firms are inefficient in expectation. However, if the planner were to learn that the true social cost is c_L, a low tax would be strictly preferable, as both firms are efficient. Thus information about firm types alone can't provide full information payoff.

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