A Principal-Agent Approach to the Delegation of Regulatory Authority

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Abstract: This paper applies a multitasking model of moral hazard to study the delegation of regulatory authority for health and environmental risks. The model characterizes conditions under which single and multiple bureaucratic agencies are optimal, and relates these findings to discussions of appropriate regulation of agricultural biotechnology.

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1. Introduction

This paper analyzes the impact of regulatory structure on policy outcomes in the regulation of health and environmental risk. Structure arises from the delegation of regulatory authority by the legislature, which enables the development of the expertise needed to resolve technical regulatory matters (Wilson, Rosenbloom). Along with the specific expertise, the delegation creates informational asymmetries between and among the legislature, the bureaucracy, and the regulated firms. These informational issues exacerbate the tension between the political control of the bureaucracy and the independent application of its expertise raising questions about oversight and the potential capture of the bureaucracy (Sunstein). Since different choices about delegation create different informational environments and different incentives for the actors, this paper explores how the choice about how to delegate regulatory authority impacts on the formulation and implementation of policy, and ultimately on social welfare.

The development of agricultural biotechnology provides an interesting and important example of the relevance of the study of the structure bureaucracy. In addition to the uncertainties inherent in a new and evolving technology, regulatory issues are complicated by the fact that the responsibility for regulating the risks of the products has been distributed among several agencies. While early legislative proposals considered consolidating authority in a single agency Congress ultimately passed no new legislation, leaving existing agencies with the task of regulating based on a variety of statutes that predate the technology (Krimsky1982, 1991). As a result, the Environmental Protection Agency (EPA), the Food and Drug Administration (FDA), and the Department of Agriculture (USDA) became the agencies primarily responsible for environmental, health, and field testing risks, respectively. This distribution of responsibility need not imply ineffective regulation, and aspects of this approach have been defended in an independent review (NRC). The goal of this paper is to clarify the conditions under which these multiple delegations are likely to be socially beneficial.

This study derives hypotheses about regulatory structure using models of hierarchy that build on models first applied to the firm. Tirole outlines some of the differences that arise when modeling government instead of private firms. Two that are relevant to this study are that, first, a government is likely to have multiple goals, some of which may be difficult to measure and, second, as has already been stressed, governmental objectives are often pursued through multiple principals. As a result of the first difference, informational problems in government are likely to be more severe than in the private sector, and incentives are weaker with payments less closely tied to outcomes (see also Dixit 1996). This weakening of incentives within the bureaucracy leaves scope for a choice of mission; the weight given to any particular goal may be susceptible to the intrinsic interests of the bureaucrats or capture by special interests.

With regard to multiple principals, Tirole notes that no one is delegated the responsibility for maximizing social welfare. Instead, each agency receives specific responsibilities, such as promoting the interests of industry, or of public health, worker safety, environmental protection and so on. An element of competition may exist among the agencies, which yields incentives for a more complete discovery of relevant information. Delegation then can potentially counter the incentive problems created by the multiple goals of government. Alternatively competition may be destructive, with the agencies differing objectives creating frictions.

The multiple goals and the multiple principal nature of government have been studied in environments with adverse selection (Martimort 1995, Martimort 1999), and moral hazard (Dixit 1996, 1997). In all of these models the aggregate incentives for the regulated firm, are weakened relative to the benchmark single principal program. This result arises from the strategic interaction of the multiple principals, who may free-ride on the others incentives, as in Martimort (1995), or compete wastefully for the agent's effort as in Dixit. Martimort (1999) explains the prevalence of multiple principal regulation through dynamic effects that counter the low-powered incentives in the adverse selection framework. This paper, similarly, extends the basic findings of

Dixit's moral hazard model by introducing countervailing effects that have been relevant to risk regulation.

The model presented below is an adaptation of Dixit's study of moral hazard in politics (Dixit 1996, 1997). His approach incorporates both the common agency model of Bernheim and Whinston and agent multi-tasking developed by Holmstrom and Milgrom. In the application to regulation, a firm is the agent of either single or multiple principals who represent the regulatory agencies[1]. Dixit argues that common agency of this type is "perhaps the quintessential feature of a process of political management of an economic activity" (Dixit 1996 p.157). While this model is preliminary in some respects, particularly because it offers a reduced form of the bureaucrat's objectives, it derives clear predictions about the incentives that result from the legislative super-principal's choice of delegation to single or multiple principals. In addition, this adaptation explores the tradeoffs between agency competition, and expertise that arise when multiple principals are chosen. The model also examines how constraints on regulators by a "super-principal" can ameliorate the problems of multiple principal regulation. This extension formalizes the notions of regulatory coordination that have been instituted in the regulation of biotechnology (OSTP), and have been suggested in efforts to reform risk regulation more broadly (Breyer).

2 A Model of Regulatory Structure

In what follows, Dixit's general model of *n* principals and *m* tasks is adapted and presented as a two by two model in order to explore relevant aspects of the regulatory structure for genetically modified organisms. Specifically, I focus on the behavior of two government agencies, representing the EPA and the FDA, that have the authority to approve the marketing of

[1] The legislature's choice is not modeled explicitly, the relation between the regulators and the firm are modeled order to focus on the consequences of the different types of delegation. Throughout the paper "principals" will refer to the regulatory agencies, and "agent" to the firm. The legislature and executive branches will be conceived of as a "superprincipals" when necessary.

a new genetically modified food. The agencies, as principals, induce their common agent, the firm, to evaluate the potential health and environmental risks of the product. The risk assessment procedure is inexact and so the effort devoted to determining the characteristics of the product is linked imperfectly to the ultimate realization of hazards, creating a moral hazard.

The model below represents the inducements to the agent, as well as the benefits accruing to the principals, in terms of transfers and utilities as is common in the principal agent literature. Dixit notes that this representation, in the context of interactions between firms and the government, stands in for a more complicated bargaining game. While the actual objective functions particularly of the regulatory bodies, can be quite complex (see Wilson), this model abstracts from these issues in order to sharpen the focus on how the choice of structure affects the incentives faced by the regulated firms.

2.1 The Model

A firm interested in marketing a new product is required to determine the potential health and environmental impacts of its introduction by performing risk assessment activities. The assessment efforts are represented by a vector, t, where $t' = [t_1 \quad t_2]$ and the subscripts stand in for evaluations of the environmental risk and human health risk, respectively. Efforts are increasing in *t,* which is imperfectly observable to those outside the firm. Effort is linked to an observable outcome *x* through the technology, $x = t + \varepsilon$ with $x' = [x_1 \quad x_2]$ and $\varepsilon' = [\varepsilon_1 \quad \varepsilon_2]$ a random shock. ε is assumed to be normally distributed with mean 0 and variance-covariance matrix Ω. The uncertainty captured by the variance-covariance matrix is a measure of the expertise of the regulatory agency, which in this general formulation includes the difficulty of discerning the reliability of the risk assessment task. For purposes of exposition Ω is assumed to be the identity matrix.

Two principals, representing government agencies have the job of motivating the firm to perform the risk assessment tasks. The principals, who are assumed to be risk neutral, have the objective functions $b_i' x - z_i \quad i = 1,2$, where $b_i' = [b_{i1} \quad b_{i2}]$ represents the marginal valuations of the components of output for the i^{th} principal and z_i the principals transfer to the agent. $z = z_1 + z_2$. The expected returns for the i^{th} principal are given by $E\left[b_i' x - z_i\right] = b_i' t - z_i$. Consistent with the ordering of tasks in the notation related to efforts, principal 1 represents the EPA and principal 2, the FDA.

Multiple principle regulation naturally raises the question of coordination of the activities of the regulatory authorities. In this model two types of coordination are considered. The first is the case in which each of the principal's responsibilities is clearly defined and not overlapping with that of the other regulator. Successful implementation of this type of coordination implies that the EPA's benefit function is associated only with the environmental risk, and the FDA's only with the food risks, so that $b_{ij} = 0, i.j = 1,2, \quad i \neq j$. An additional coordination issue arises due to non-cooperative behavior in the provision of incentives. This issue is introduced below and is discussed in greater detail in section 2.2.2

The regulated firm is risk averse and is assumed to have a utility function that is captured by constant absolute risk aversion where $u(w) = -\exp(-rw)$ and $w = z - \frac{t'Ct}{2}$, C is two-by-two matrix of the effort cost parameters and r is a measure of the agents risk aversion. The structure of C, which reflects the extent to which efforts are complements or substitutes, has an important effect on the power of incentives. In general, the off-diagonal elements are unrestricted with respect to sign. If positive, the marginal cost of an effort is increasing in the other effort, $\frac{\partial^2 t'Ct}{\partial t_1 \partial t_2} > 0$, and so the efforts compete in the firm's objective. Alternatively, the cross partial may be decreasing.   This would be the case, for example, when the effort devoted to evaluating health risks reduces the marginal costs of the environmental risk assessment, since the human and animal health effects of the product may be quite similar. More generally, advances in understanding the implications of expression of the transferred genetic material, that arise with respect to one task, may have an effect on the cost of the other. Both of these considerations suggest that the case of strategic complements, where the off diagonal elements are less than or equal to zero is likely to be the more relevant case. The analysis below begins by assuming C is diagonal and explores alternatives with reference to this benchmark.

This note derives results for a multitasking agent under first, second, and third best conditions. In the first best, there is full observability, and so contracts are formed directly on the agent's effort. The second best results when efforts are unobservable and incentives are the choice of a single principal. The introduction of an additional principal creates a "third best" environment, since the optimal incentives for the agent are affected by the non-cooperative behavior of the principals.

Case 1: Observable effort

When the efforts of the firm are observable, $\varepsilon = 0$ and $t = x$. The first best solution results from the maximization of the expected surplus of the principals and the agent, $b't - t'Ct/2$, with the transfer z assumed to satisfy the participation constraint.

The first order condition yields

$$t^* = C^{-1}b. \qquad (1)$$

with the optimal level of effort maximizing welfare.

Case 2: Unobservable Effort

When the effort of the firm is unobservable, the regulators condition their payments on x. As in Dixit, I assume an aggregate payment scheme that takes the linear form $z = \alpha' x + \beta$. Each regulatory agency then proposes $z_i = \alpha_i' x + \beta_i$, where $\alpha_i = [\alpha_{i1} \quad \alpha_{i2}] \quad i = 1,2$, with the first subscript denoting the principal and the second the task. This transfer, metaphorical as noted above, represents the expectation of profits as well as liabilities for harms from the product as well as the expected benefits or costs in continued dealings with the regulatory authority that arise from the current risk assessment. The expected utility of the firm is given by

$E[U_A] = E\left[-\exp\left\{-r\left(\alpha' x + \beta - \frac{1}{2} t' C t\right)\right\}\right]$. Applying the moment generating function of the multivariate normal, yields $E[U_A] = -\exp\left\{-r\left(\alpha' t + \beta - \frac{1}{2} r \alpha' \Omega \alpha - \frac{1}{2} t C' t\right)\right\} = -\exp(-ry)$, with y the certainty equivalent income of the uncertain prospect and β a transfer that is assumed to satisfy the participation constraint. The agent chooses t to maximize

$\alpha' t + \beta - \frac{1}{2}(r\alpha' \Omega \alpha + t' C t)$ which yields, at the optimum, the second best effort level

$$t^{**} = C^{-1}\alpha. \qquad (2)$$

A comparison of (1) and (2) makes clear that when $\alpha = b$ the first best results. By exploring the regulators programs we can see that, when effort is unobservable, this will not be the case.

With a unified regulatory authority, the joint surplus can be expressed as

$bC^{-1}\alpha - \frac{1}{2}\alpha'(C^{-1} + r\Omega)\alpha$ and the first order condition implies that

$$b = (I + rC\Omega)\alpha^{*}. \qquad (3)$$

With $rC\Omega > 0$, $\alpha^* < b$ and the incentive to devote effort to the assessment tasks is weakened relative to the first best[2]. In a multiple principal framework, the choice of incentives is made strategically, considering not only the firm's solution (2) but also the fact that the other regulator is eliciting efforts to meet its own objectives.

In a strategic setting, each principal chooses their incentives to maximize their bilateral surplus with agent, taking the other principal's choice as given. The bilateral benefit for the environmental regulator and the agent is given as

$$b^{1'} C^{-1}\alpha^1 - r\alpha^{2'}\Omega\alpha^1 - \frac{1}{2}\alpha^{1'} C^{-1}\alpha^1 - \frac{1}{2}\alpha^{1'} r\Omega\alpha^1 . \qquad (4)$$

Maximizing (4) with respect to α_1 and solving for b_1 yields $b_1 = (I + rC\Omega)\alpha_1 + rC\Omega\alpha_2$ with α_1 defined implicitly as a best response to α_2. Repeating for principal two and summing the optimality condition over both principals yields the aggregate benefit scheme

$$b = (I + 2rC\Omega)\alpha^{**} . \qquad (5)$$

A comparison of (5) and (3) illustrates the weakening of incentives that is at the heart of multiple principal regulation. In the non-cooperative outcome of (5) the term that creates the wedge between the first and second best is magnified, thus shifting effort to a "third best" result[3]. A more careful examination of the bilateral surplus in (4) clarifies why this weakening occurs.

Consider the incentives for the environmental regulator, principal 1, to induce effort for assessment of the health risk, task 2. If the principal neglects this dimension of the firm's task, the incentives are $\alpha_1 = [\alpha_{11} \quad 0]$. But as is demonstrated below, the environmental regulator has a profitable deviation, that of making $\alpha_{12} < 0$. The health regulator is similarly motivated in its

[2] When the off-diagonal elements c_{ij} are less than zero it is necessary that $|c_{ij}| < c_{ii}$ for the weakening of incentives to hold.

[3] In general the factor that captures the weakening of incentives is $nrC\Omega$ where n is the number of principals.

evaluation of food safety and so, in a non-cooperative setting, the equilibrium incentives reflect the losses due to the competition for effort by the regulators.

The negative incentive implies that the agent pays principal 1 for the effort put into task 2. The net effect of the interaction is that an equilibrium exists in which the compensation provided by the principal moves closer to a fixed rather than variable payment. These results suggest that some oversight or restrictions on the regulator's ability to penalize the firm could be beneficial. Before exploring this issue I consider the impact of different cost structures on the magnitude of penalties.

In the base case with *C* diagonal and $b_{12} = 0$ the first order condition with respect to α_{12}, yields $b_{12} = \alpha_{12} + rc_{22}\sigma_{22}(\alpha_{12} + \alpha_{22}) = 0$. Manipulation of this result yields

$$\alpha_{22} = -\alpha_{12}\left(\frac{1}{rc_{22}\sigma_{22}} + 1\right). \qquad (6)$$

Since each principal provides positive incentives for the action it is interested in, $\alpha_{22} > 0$, and therefore $\alpha_{12} < 0$. With $rc_{22}\sigma_{22} > 0$, the magnitude of principal 1's disincentive is smaller than that of principal 2's incentive, $|\alpha_{22}| > |\alpha_{12}|$, so that there are positive incentives for the two tasks in the Nash equilibrium. Note also that the difference in the magnitude is shrinking with a noisier information structure as expected. As the link between actions and outcomes becomes less clear, it becomes less efficient to try to motivate through incentives, since more of the funds are inefficiently passed through to the other principal. As a result, the principals move towards an incentive scheme that relies more on fixed payments.

When *C* is not diagonal the analysis is slightly more involved, due to the interaction of the incentives for the different tasks. A more general formulation of (6) yields,

$$\alpha_{22} = -\alpha_{12}\left(\frac{1}{c_{22}} + 1\right) - \frac{c_{21}(\alpha_{11} + \alpha_{12})}{c_{22}} \qquad (6a)$$

when $r = 1$ and $\Omega = I$, which are assumed to clarify the exposition. The magnitude of the penalty that the EPA chooses for the health assessment task depends on the sign of the off diagonal term. When c_{21} is less than zero, the incentive to penalize the agent is diminished.

2.2 Explaining Multiple Principal Regulation

2.2.1 The Role of Expertise

Given that multiple principal regulation results in diminished incentives, the question arises as to why it exists. In the following sections we introduce two issues that have been important in the regulation of agricultural biotechnology that can mitigate or offset the social costs that arise from the multiple principal structure. The first of these is related to the existence and development of expertise in the bureaucracy, and the second to the possibility of regulatory coordination by a legislative or executive branch super-principal.

The delegation decision has been explained by the need for expertise (Sunstein). In the multiple principal framework, each principal has a specific expertise related to the product or to an aspect of its effects, such as on human health or the environment. In the modification that follows expertise is modeled as the ability to make a more reliable observation of the agent's behavior, so that the noise in the information structure is smaller when expertise increases. Multiple principal regulation can make sense when the degradation of incentives resulting from the non-cooperative behavior is offset by increased expertise in the individual agencies. Recalling the basic result from (3) and (5) we consider the question of whether incentives are greater under single or multiple principal regulation.

In the base case, with C and Ω diagonal, and $\alpha_i^k, \quad k = S, M, \quad i = 1,2$ representing the incentives under single and multiple principal regimes for the two tasks, equations (3) and (5) imply that $\alpha_i^M > \alpha_i^S$, and $M \quad S$ when $\sigma_{ii}^S > \frac{\sigma_{ii}^M}{2}$, where the σ_{ii}^k's are the appropriate variances in the Ω^k matrices.

2.2.2 A Coordinated Framework

This section extends the coordination of the principals, which has until now focussed on the correspondence between tasks and benefits, to include coordination in the provision of incentives. This coordination is imposed by a super-principal, from either the legislative or executive branches and results in a constrained Nash equilibrium. In its most extreme form, this constraint prohibits the principals from instituting a penalty for effort devoted to the other principal's task. The feasible incentive schemes include incentives only for the activity of interest to the principal. More generally, the principal may be constrained so that its fines on the agent are not as large as in the non-cooperative setting. This section outlines the first case of perfect coordination as an example and then derives the conditions for the optimal regulatory structure given imperfect coordination by the super-principal. The final section combines the coordination results with those related to gains in expertise due to delegation in order to generate general conditions on the optimal structure.

In the coordinated framework, the principals still formulate their incentives strategically. The constraint on the $\alpha_i \quad i = 1,2$, however implies that the bilateral surplus between agent and principal 1 in equation (4) reduces to a form that omits concern for principal 2's task of interest. With $b_1' = [b_{11} \quad 0]$, $\alpha_1' = [\alpha_{11} \quad 0]$, and $\alpha_2' = [0 \quad \alpha_{22}]$, principal 1 chooses α_{11} to maximize $b_{11}\Gamma_{11}\alpha_{11} - \frac{1}{2}(\alpha_{11})^2(\Gamma_{11} + r\sigma_{11})$ where Γ_{11} and σ_{11} represent the elements from the first row and column of C^{-1} and Ω respectively. $\Gamma_{11} = \frac{1}{c_{11}}$ when C is diagonal, but more generally, $\Gamma_{11} = \frac{c_{22}}{|C|}$ where $|C|$ is the determinant of C. The first order condition yields

$b_{11} = \left[1 + \frac{r\sigma_{11}}{\Gamma_{11}}\right]\alpha_{11}$. The coordination restores the second best since the aggregate benefit

function does not result in the magnification of the term that weakens incentives. The resulting aggregate benefit is $b = (I + rC\Omega)\alpha$, as in equation (3).

When C is not diagonal the possibility of improving on the second best exists. Substituting $\Gamma_{11} = \frac{c_{22}}{|C|}$ in the first order condition, yields, $b_{11} = \left[1 + \frac{r|C|\sigma_{11}}{c_{22}}\right]\alpha_{11}$. When the

tasks are close complements the terms in the C matrix are approximately equal in absolute value, and $|C| \to 0$. Thus, when the superprincipal effectively constrains the principals, $\alpha_{11} \to b_{11}$ approximating the first best. More generally, when the principals are imperfectly constrained it is clear that there is some improvement in incentives.

From the first order condition for task 1, $\frac{\partial \alpha_{11}}{\partial \alpha_{21}} = -\frac{r\sigma_{11}c_{11}}{\Gamma_{11} + r\sigma_{11}} = -\frac{R_1}{1+R_1}$, where

$R_1 = r\sigma_{11}c_{11}$. This change in incentives will always fall between negative one and zero, with the extremes representing the cases of infinite risk aversion and risk neutrality. Thus, with moderate risk aversion, as the constraint takes effect and α_{21} becomes larger (less negative), principal one's incentive falls, but not as quickly, partially restoring the strength of incentives.

When the principals are constrained imperfectly, the incentive for the off task falls between zero and the unconstrained value. Focussing again on principal 2's choice for task 1,

$\alpha_{21} < \tilde{\alpha}_{21} < 0$, where $\alpha_{21} = -\frac{b_{11}R_1}{1+2R_1}$. Maximizing the constrained objective yields

$\tilde{\alpha}_{21} = -\dfrac{b_{11}R_1}{1+2R_1}\theta$ where $\theta \in (0,1]$ represents the stringency of the constraint, with $\theta = 1$

unconstrained state. The aggregate incentive under the imperfect constraint is

$$\tilde{\alpha}_1 = \frac{1+R_1(1-\theta)}{1+2R_1} \qquad (7)$$

2.3 General Results on Regulatory Structure

Combining the results related to expertise and regulatory coordination yields the following conditions on the choice of regulatory structure. The multiple principal structure (M) is preferred to a single principal (S) when gains from coordination and expertise are sufficient to counter the degraded incentives arising from non-cooperative behavior. M S when $\alpha^M > \alpha^S$. The inequality depends on θ_i, the stringency of the constraint for task *i*, and the magnitude of $\sigma_{ii}^S - \sigma_{ii}^M$, representing the gains from expertise. From equations (3) and (7), the choice between the structures can be expressed so that when

$$\theta_i < \frac{\sigma_{ii}^S - \sigma_{ii}^M}{\sigma_{ii}^M\left(1+R^S\right)} + \frac{R^S}{1+R^S}, \quad M \quad S.$$

3 Discussion and Conclusion

Regulatory policy exists in an environment where tradeoffs between science based expertise and political considerations are common. The conditions derived from this analysis of regulatory influence on firm behavior suggest the types of problems that regulators interested in implementing science-based policies must address. Distributed authority may create expertise that is inaccessible if problems arising from non-cooperative behavior are severe. While coordination mechanisms have been suggested and implemented, controversy about the adequacy of regulation has not been eliminated. The difficulty of this problem suggests several points where this basic framework could be usefully extended.

First it is useful to consider that the ability to constrain the behavior of the regulatory agencies is likely to be inversely related to the gains from expertise. When observability of the firm increases due to delegation, the regulatory principals have an exploitable informational advantage over the super-principal. This issue suggests that an analysis that nests the issue of firm incentives in a model that directly incorporates the political control of the bureaucracy would yield additional insights.

An implication of this line of thought is that the additional informational problem raises questions about the possible effectiveness of coordination. A related line of research suggests that as a coordinating body attempts to address the informational gaps perverse results of either under or over regulation are likely to occur. McCubbins and Schwarz propose that political bodies responsible for regulatory oversight often respond to "fire alarms" rather than incur the costs of regular monitoring through "police patrols". Hopenhayn and Lohmann have applied this reasoning and the fact that it is interest groups who often pull the alarms, to explain over and under regulation of risks. These final comments which extend beyond the scope of the paper, suggest that the tension between political control and scientific expertise in the regulation of risk is deeply embedded in democratic institutions. It is hoped that the analysis presented above clarifies some important aspects of the underlying mechanisms.

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