How Much Discretion for Agencies? A Political-Economy Perspective on Risk Regulation[1]

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November 19, 2008

Very preliminary Draft. Comments most welcome.

Abstract: We analyze Congress' choice on the optimal degree of discretion left to an agency in regulating firms which are involved in socially risky activities. Firms may affect the probability of a damage by exerting some nonverifiable level of safety care. The optimal degree of discretion trades off the benefits of having discretionary policies tailored to the agency's expert information on realized damages and the cost of having that agency implement policies that might excessively favor the industry. Full discretion is optimal in contexts where risk regulation is efficient despite downstream moral hazard. Partial (and sometimes no) discretion is optimal when downstream moral hazard calls for leaving a positive liability rent to firms. Less conflict of interests between Congress and the agency, more uncertain distributions of damages in the sense of Blackwell, or "higher" damages, are political and economic conditions that call for increasing the agency's discretion. In several extensions, we study how this degree of discretion varies with the technology adopted by the firm, with asymmetric information on the regulator's preferences and when the agency is strategically appointed by the Executive.

JEL Classification: D02, D82, H11, L51.

Keywords: Risk Regulation, Agencies, Rent/Efficiency Trade-Off, Rules versus Discretion.

[1]We thank Marie-Pierre Boé for assistance and the Agence Nationale pour la Recherche for its financial support. We also thank seminar participants in Toulouse for helpful comments. All errors are ours.

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1 Introduction

The regulation of risk differs significantly from one domain to the other not only in terms of the economic risks and benefits at stakes but also in terms of the actual regulatory institutions (agencies and procedures) designed to cope with the issues at hands.[1] In some fields, agencies are left with significant discretion in setting up standards and fines for misconduct, evaluating costs and benefits of allowing new products free of much constraints. In others, safety standards are mandatory, and norms across domains and market conditions are the rule.

Evidence on both sides are pervasive. In a significant and often referred to piece, Van Houtven and Cropper (1996) indicated for instance that the EPA enjoyed significant discretion in setting up regulatory standards to allow chemical risks, counting both costs and risks, even though extant legislations and statutory guidelines were emphasizing only the risk side. In a similar vein and confirming the huge discretion de facto left to the EPA when controlling Superfund sites, Hird (1993, 1994) also reported that the relevant Congressional oversight committee had little or no impact on the pace of cleanups at sites in districts of those committee's members. On the other hand, the history of safety and health regulation in the U.S. shows that the Occupational Safety and Health Act forced the OSHA agency to adopt voluntary industry safety standards as mandatory regulations ignoring any benefit-cost analysis based on whatever expert information this agency could have. Along similar lines, an often observed and controversial feature of liability regimes is that agencies are often bound in the fines they can impose on firms inflicting damages to third-parties through their activities. The Price-Anderson Act in the U.S. and the Nuclear Liability Act in Canada are archetypical examples of regulations that impose such limits for operators of nuclear power stations involved in off-site damages.[2] Similar limits are found also for oil pollution.[3]

Although casual thinking suggests that variations in the nature of risk and the political forces at play might cause different sorts of corrective policies which in turn might require variations in institutions, a more detailed study is needed to understand the precise mapping by which it is so. Offering such study is our broad goal in this paper. More specifically, we turn to the precise relationships between Congress, the agency and the

[1]See for Hood, Rothstein and Baldwin (2003) for some account of that.
[2]Heyes and Liston-Heyes (2000) argue that this can be viewed as an implicit subsidy for the operators.
[3]See for instance, Jin and Kite-Powell (1999).

firms concerned by risk regulation to understand first, how much freedom should be left to regulatory agencies in designing risk regulation, and second what are the economic and political forces that shape this discretion.

In a nutshell, the bottom line of our analysis is that, although some kinds of rules and constraints on agencies are always optimal, a number of technological and political forces push also towards leaving them with a minimal amount of discretion. On the technological side, agencies should have more discretion in more uncertain environments, when risks are more significant, when firms have some control on the distributions of those risks. On the political side, although uncertainty on the preference of the regulator has an ambiguous impact on discretion, strategic appointments of regulatory agencies' heads by the Executive favor again more discretion.

Basic ingredients: Consider a firm involved in activities that put society or the environment at risk. Expected damages and harms on third-parties can be reduced if the firm exerts some level of safety care that is nonverifiable and privately costly although socially attractive. This moral hazard problem calls for corrective policies. An incentive regulation is designed properly incentivize the firm to exert effort. Congress delegates to some extent the tasks of choosing and implementing such policy to a regulatory agency. Such delegation is justified in the first place by the fact that the agency has also all expertise to tailor incentive payments to the actual realizations of damage and has thereby an informational advantage vis-à-vis Congress. However, the agency's regulatory mandate may be constrained by Congress that may put limits on what the agency can do.

In this context, our main results are the following:

Full discretion with no downstream moral hazard: We first show that the scope for delegation depends on whether or not regulatory policies are efficient or not.

Suppose first that the firm has enough wealth to cover the damage it may inflict on society. Downstream moral hazard can then be solved at no cost by making the firm residual claimant. Corrective policies can be efficiently designed: The firm can pay for any damage it inflicts on society.

In such settings and even though Congress and the agency may differ in the weights they respectively give to the firm's profit in their respective objective functions, they certainly agree on imposing this Pigovian tax. There are no costs and only benefits of delegation coming from the possibility of using the regulator's expert information to tailor that Pigovian tax to the exact value of the damage.

Partial (or no) discretion otherwise: Things are rather different when downstream moral hazard on the firm's side causes a true agency problem that undermines optimal regulation. Suppose the firm has not enough cash to cover damages and is now protected by limited liability. To induce effort, the optimal regulation can no longer punish for bad performances but must now reward for good ones. This leaves some liability rent to the firm which is socially costly. When the regulator and Congress hold different views of that cost and give different weights to the firm in their objective functions, leaving discretion to the better informed regulator is now costly from Congress' viewpoint. Even though, delegation allows to better use the regulator's private information, it also implies choices that may be excessively tilt towards the industry in case the regulator has a pro-firm bias.

In other words, the downstream agency problem triggers an upstream agency problem between Congress and the regulatory agency itself. More specifically, the "pro-firm" regulator may inflate possible damages in order to make it more attractive to induce the firm's effort which can only be made by giving it more liability rent. To avoid such behavior, Congress imposes an upper bound on possible fines and rewards, which limits the scope for regulatory manipulations.

Making use of the recent mechanism design literature on delegation,[4] we characterize the optimal trade-off between setting a rule that applies irrespectively of the level of damages and leaving discretion to the regulator to set up a policy tailored to that particular level. Leaving full discretion to the agency is no longer optimal: Congress always gains from "capping" the regulatory choice for the upper tail of the distribution of damages where risks are very high, liability rents huge and conflicts between the pro-firm regulator and Congress certainly significant. Even worse, large conflicts might call for no delegation at all and fully rigid rules based on expected and not realized damages. This so-called *"Ally Principle"*[5] according to which delegation is more pronounced when Congress and the agency have similar preferences on what should be the optimal rent/efficiency trade-off

[4]See Holmström (1984), Armstrong (1994), Armstrong and Vickers (2008), Melumad and Shibano (1991), Martimort and Semenov (2006, 2008) and Alonso and Matouscheck (2008) among others.

[5]See Huber and Shipan (2006) for a nice survey of results in the political science literature built on that principle. Note however that this result is often found in that literature by restricting the kind of ex ante instruments that Congress can use to curb the agency's behavior. No such restrictions are made in our mechanism design analysis below.

in a second-best world,

Comparative Statics: Beyond, we provide several comparative statics results showing how changes in the distribution of damages affects the optimal degree of discretion left to the agency. This is an important step to have a broader picture of the mapping between the kind of uncertainty that surrounds the regulated activity and what sort of institutions we should expect.

In this respect, we first show that more "front-loaded" distributions, i.e., distributions giving more weights to low damages, justify giving less discretion to the agency. This result is rather consistent with our previous findings that the major problem of a "pro-firm" agency is to exaggerate damages justifying thereby higher powered incentive regulations that shift more rent to the private sector. Indeed, when most of the damages are low enough, a claim for high damages is unlikely unless it signals a "pro-firm" manipulation by the agency.

Second, we investigate how the amount of discretion left to the agency evolves when the distribution on damages is better known, maybe thanks to the evolution of scientific knowledge. We model the evolution of scientific knowledge as the arrival of public information that decreases uncertainty on the distribution of damages in the sense of Blackwell.[6] Under some weak assumptions, we show that leaving more discretion to the agency is preferable in less certain contexts. Instead risks which are better known call for more rigid rules.

We then investigate several important extensions of our basic framework that stress in which directions the trade-off between regulatory rules and discretion should be tilt when various technological or political changes are considered.

Endogenous distributions of damages: We first endogenize the distribution of damages as coming from a non-contractible technological choice made the firm. Since higher damages require higher powered incentive regulations that provide more rent to the firm, the latter may have incentives to undertake non-verifiable investments that shift the distribution of damages "up"[7] to increase their expected rents. This strategy is all the more valuable when the regulator has more discretion. Instead, it is of no value in front of a rigid policy that does not respond to the regulator's expert information and leaves to the

[6]See Gollier, Jullien and Treich (2000) for a similar modeling of scientific progress.

[7]In a sense that we define precisely in the text.

firm a rent which is independent of the distribution of damages.

Uncertainty on the regulator's preferences: We analyze how the optimal degree of discretion left to the agency depends on uncertainty on its own preferences. This analysis is of significant importance to understand both the case where the agency has intrinsic private information on how it evaluates the rent/efficiency trade-off and the case where political fluctuations in the Executive branch may also generate such uncertainty through the appointment process. We characterize the optimal trade-off between rules and discretion in such environment. The analysis is made complex because of the interplay between two pieces of private information that the regulator handles: first, the realized level of damage and second his own preferences on the rent/efficiency trade-off. We show that, roughly, the amount of discretion left to the agency changes only by a second-order magnitude as one adds a little bit of uncertainty on the regulator's preferences. However, this second-order effect depends in fine ways on the underlying uncertainty on preferences. Nevertheless, our model suggests that the amount of discretion should slightly decrease when the distribution of the regulator's preferences is rather single-peaked. Instead, the agency should have more discretion when this distribution has more variance.

Strategic delegation: We then open further the black-box of the relationships between Congress and the agency by making explicit the appointment process. We show how an Executive with a pro-firm bias may strategically appoint a regulator whose preferences are closer to Congress than his own to increase discretion and thereby favors the private sector. This in turn favors the Executive's objectives. At equilibrium, the agency's preferences correspond somewhat to a strategic compromise between those of the Executive and those of the Congress.

Section 2 reviews the relevant literature. Section 3 presents the model giving a clue of the possible conflicts of interests between Congress, the agency and the regulated firm in our framework. Section 4 shows that the conflict of interests between Congress and the agency comes at no cost for society when moral hazard on the firm's level of safety care does not generate agency cost. Full discretion should then be granted to the agency. Section 5 demonstrates that such conflict arises when moral hazard downstream really matters and induces a true rent/efficiency trade-off. Partial discretion follows. We provide there a number of comparative statics results with respect to the degree of conflict between the agency and Congress and with respect to the underlying distribution of damages.

Section 6 endogenizes the distribution of damages by making it an explicit technological choice of the firm. Section 7 investigates how the amount of discretion is affected by either intrinsic private information that the regulator may have on his own preferences on the rent/efficiency trade-off or by politically induced fluctuations on those preferences. Section 8 analyzes the strategic choice of the regulator by the Executive. Section 9 briefly concludes by pointing out alleys for further work. All proofs are relegated to an Appendix.

2 Literature Review

Our paper belongs and deepens several trends of the literature which cover both fields of economics and political science.

Regulation and political economy: The so-called *New Economics of Regulation*[8] developed, among others, by Baron and Myerson (1982) and Laffont and Tirole (1993) starts from the important hypothesis that the preferences of the regulator in charge for correcting an externality or controlling market power are exogenously given and, for most of this literature, that there is no conflict of interests between that regulator and Congress. The main focus is on the design of optimal incentive regulations in a second-best environment where corrective interventions are informationally constrained by an adverse selection problem. Second-best regulations result then from a true trade-off between looking for efficiency and leaving to regulated firms some information rent which is socially costly. Those optimal regulations generally make use of all information available to regulators and, as such, they have been sometimes criticized for being too flexible. Introducing a difference in the preferences of Congress and the agency over what should be the optimal trade-off as we do hereafter paves the way to a more relevant analysis. That conflict forces Congress to design the scope for the agency's discretion and optimal regulations may often look like rigid and non-discretionary policies.

Building on the insights of the *New Economics of Regulation,* Laffont and Tirole (1993, Chapters 11 and following), Laffont and Martimort (1999) and Martimort (1999) among others have somewhat opened the black-box of the relationship between Congress and agencies. Those papers argue that regulatory capture is at the source of the conflict between Congress and the regulator. We share with this literature the view that this

[8]Laffont (1994) coined this terminology.

conflict is better solved by making optimal policies being less sensitive to the agency's expert information. In those papers, that reduced discretion comes with lower regulatory budgets and low-powered incentive regulation although it never boils down to a complete rigid rule as it is the case here. A major difference between that line of research and ours is that it relies significantly on the possibility for Congress to incentivize the agency with performance pay. Instead, our focus on "rules versus discretion" departs from this assumption. This seems to us a better modeling of the crude ex ante control[9] that Congress exerts on the agency through legislations and restrictions in procedures.

Still pushing further the informational paradigm of the *New Economics of Regulation,* other authors have analyzed how various political games influence the preferences of an agency and the regulations that it implements. Baron (1989) pointed out argues that preferences on the rent/efficiency trade-off are inherited of the equilibrium between political forces in the legislature itself. We share with this paper the view that conflicts between political forces arise if and only if asymmetric information undermine regulation. We pushed further that important insights by recognizing that the regulator's expertise may then also trigger an agency problem upstream between Congress and the agency and that induced agency problem must be solved with some form of ex ante control. Laffont (2000) argued that a constitutional commitment to fully rigid regulations may be ex ante preferred to a solution leaving more discretion to political principals when they differ in their preferences on the rent/efficiency trade-off. The idea is that, although those principals choose different points on the interim efficiency frontier of what can be achieved under asymmetric information, political fluctuations in the identity of the leading principal brings the average policy away from that boundary. Applying that idea to environmental regulation, Boyer and Laffont (1999) showed that simple standards may be ex ante preferred to optimal regulations because they come "on average" closer to the interim efficiency frontier. Although our results obviously share some flavor with this idea, several noticeable differences remain. First, the Laffont's framework does not distinguishes between elected political principals and agencies as we do.[10] Second, the rule to which more discretionary policies are compared is exogenously given whereas we derive the optimal trade-off between rules and discretion without any ad hoc restriction.

[9]See the seminal papers by McCubbins, Noll and Weingast (1987, 1989) on the role of such ex ante control in curbing bureaucratic drift.

[10]On this point, Faure-Grimaud and Martimort (2003) analyzed how the scope for regulatory capture depends on the relationships between short-term political principals whose identity may fluctuate upon elections and long-term independent agencies.

As we argue below, the trade-off between imposing rules on agencies or leaving them with considerable discretion opens strategic gaming for the Executive through the appointment process. The idea that the Executive can strategically choose an agent in a strategic context is reminiscent of several branches of economics going from industrial organization (for instance Besanko and Spulber (1993)) to macro and public finance (Rogoff (1985), Giavazzi and Pagano (1988), Person and Tabellini (1993) among many others). Those literatures have repeatedly argued that governments or society at large may solve a commitment problem by delegating control to agencies with "biased" preferences. Commitment per se is not an issue in our context; instead the compounding of the agency's expertise and of conflicting interests between different branches of the government justifies those biases.

Political science: How much Congress delegates or should delegate to agencies has been a recurring theme of the political science literature over the recent years. The so-called *Congressional Dominance Theory* (McCubbins and Schwartz (1984), and Weingast and Moran (1983)) and the *"Shift The Responsibility"* approach (Fiorina (1982)) both pushed the view that Congress could perfectly control agencies without any agency cost. As convincingly argued by Epstein and O'Halloran (1999, p. 74), this seems quite at odds with the mere observation that *not everything* is delegated. In an important book that has had since then a significant influence on the field, these authors built a theoretical model which shares much flavor with ours. As a result, they also prove a version of the "Ally Principle" showing (and confirming through some empirical analysis) that more delegation occurs when Congress and the agency have close preferences. More specifically, in a spatial model where players have given ideal policies, they consider a four-player environment with a Congressional Committee who is partially informed on some policy relevant state, a median voter in the Floor who takes the decision to delegate or not to an agency, and finally the President who may appoint regulators. This model is richer than ours in some aspects, especially in analyzing how the interaction between the Committee and the Floor affects delegation. On other grounds, our model stresses that the divergence between ideal policies of these different public bodies is not a priori given but follows from the informational constraints that shape second-best regulations. Hence, our main progress is to argue that institutional choices respond to fundamental informational problem coming from the very phenomenon why public intervention is needed in the first place. Finally, our mechanism design approach helps characterizing the largest set of delegation policies without making any ad hoc restriction. This illuminates the trade-off between rules and discretion and allows to investigate how this trade-off is modified as the political and economic environments become more complex. In particular, our mechanism design approach allow us to make clear predictions on the role that "uncertainty" be it politically or economically induced plays in affecting delegation: A theme that echoes the important works of political scientists like Moe (1989) and Horn (1995).

3 The Model

We consider the regulation of a firm whose risky activities might be harmful for society. A typical example would be a vessel shipping toxic products and whose leakages might create significant environmental damages. Another important example concerns those firms involved in producing GMO whose risk for the existing species might be major. Of course, our framework has a broader appeal and apply to any kind of risk regulation (product safety, health, etc..).

Moral hazard: By exerting some level of safety care e, the firm reduces the probability $1 - e$ that a damage of size D hurts victims or the environment. Exerting that effort entails a non-monetary cost $\psi(e)$ for the firm, with $\psi(\cdot)$ satisfying the Inada conditions ($\psi'(0) = 0$, $\psi'(1) = +\infty$ and $\psi(0) = 0$).[11] The disutility function $\psi(\cdot)$ is increasing and convex ($\psi'(e) > 0$, $\psi''(e) > 0$) and we will assume that also $\psi'''(e) \geq 0$ for technical reasons. The level of safety care is non-observable by either the firm's regulator or any third-party so that moral hazard might increase the risk of a potential damage.

The firm is endowed with a stock of assets whose value w will fall short of fully compensating victims for the harm done. That liability problem cum the non-verifiability of effort will make it impossible for the firm to fully internalize the externality that its activities might exert on victims or on the environment. This assumption of limited liability is key to first introduce the *liability rent* that accrues to the firm. This is an important assumption to analyze how optimal regulations must reach a trade-off between extraction of those rents that are viewed as socially costly and efficiency. Second, different public bodies (Congress, the agency, the Executive branch) will evaluate this trade-off in

[11] The Inada conditions ensure interior optima in all circumstances that follow. Sometimes, it will be easier to get comparative statics results by specializing the functional form to the quadratic case $\psi(e) = \frac{\lambda}{2}e^2$ in which case, we will assume that λ is large enough to ensure that optimal efforts always lie within the interval $[0, 1]$.

different ways. This will trigger an interesting gaming between those public bodies.

Contracts: A regulatory agency designs an incentive regulation in order to foster the risky venture's incentives to exert care. Without loss of generality, such regulation stipulates a base payment t from the rest of society to the firm as a reward for its activities but also a fine of f in case an environmental damage occurs, i.e., with probability $1-e$.[12]

Of course, and even though the analysis below relies significantly on the ability of the regulator to use transfers in designing the firm's regulation, a broader interpretation is available. Fines (and rewards) may not only be viewed as monetary payments that the firm has to make to compensate victims but they may also be given a more abstract meaning as including any reputational stigma that the firm may bear following an accident (or its absence). Along the same lines, the agency's choice on how much rewards and fines should be imposed on the firm could be replaced by its ability to cancel or permit some of the firm's products and activities.[13]

Players' objectives: With these notations in hands, it is straightforward to rewrite the firm's expected profit U as:

$$U = t - (1-e)f - \psi(e). \qquad (1)$$

Denoting by S the gross surplus generated by the firm's activities and merging consumers and victims as a single entity (the "rest of society") whose expected payoff is denoted V, we have:[14]

$$V = S - t + (1-e)(f - D). \qquad (2)$$

The regulator is appointed by the Executive branch of the government and his preferences reflect those of this branch.[15] Those preferences reflect a weighted sum of the payoff

[12] The assumption that the base payment t is controlled by the risk regulator is made for simplicity only. More generally, this base payment might be determined through product market considerations: It could be fixed by an economic regulator distinct from the risk regulator, or reflect the extent of competition on the product market and be driven by market/supply considerations.

[13] Hiriart and Martimort (2006) provide more motivation for the short-cut of using monetary transfers.

[14] Note that this expression makes it clear that fines are transferred at no cost from the firms to victims. It would be straightforward to include a cost of public funds λ in our framework so that (2) becomes:

$$V = S - (1+\lambda)t + (1-e)((1+\lambda)f - D) - \psi(e).$$

The lessons of our model would carry over provided that the social value and the damage are conveniently discounted by $1+\lambda$.

[15] Section 6 analyzes the case where those preferences of the regulator are chosen by the Executive through the appointment process.

of victims, consumers but also the firm's profit write as:

$$W_R = V + \alpha_R U, \qquad \text{with } 0 \leq \alpha_R < 1. \tag{3}$$

The fact that the firm's profit receives a weight less than one in the regulator's objective function captures the idea that the welfare of society at large is a greater concern for the regulator. As it is well-known from the regulation literature[16] this assumption guarantees that optimal regulation might trade off an efficiency objective with a rent extraction motive.

There is some bias between the regulator's and Congress' objectives which can be written as:

$$W_C = V + \alpha_C U \qquad \text{with } 0 \leq \alpha_C < \alpha_R < 1.$$

Congress gives less weight to the firm's profit in its objective function than the regulator. This assumption reflects the possible capture of the Executive and Administrative branches of the government by private interests and the greater influence that those interests may have on those branches.[17,18] It may also be viewed as a short-cut for the carrierist concerns of the regulator who may want to please the industry to open "'revolving doors".[19] Lastly, and borrowing Baron (1989)'s view that enacted policies reflect the preferences of the median voter in Congress, this assumption may be relevant when this median comes from a district where the firm's business is not a significant concern.

We denote by $\Delta\alpha = \alpha_R - \alpha_C$ the measure of the conflict of interests between Congress and the regulator.

Information and agency's discretion: To model in a simple way the trade-off between discretion and bureaucratic rules in the design of risk regulation, we assume that the regulator, because of his expertise, has private information on the damage D.[20] This is this informational advantage that justifies the use of a regulator in the first place even though he may have different preferences than Congress.

[16] Baron and Myerson (1982).

[17] Horn (1995) pointed out that firms whose costs can be affected by health or environmental regulation take a very active interest in the proceeding of agencies like OSHA and EPA.

[18] We will comment in Section 9 below on the case of a reverse assumption where Congress is more "pro-firm" than the agency.

[19] See Gormley (1979) and Che (1993).

[20] Alternatively, we way as well assume that damages remain to a large extent uncertain at the time of designing the regulatory charter even to the regulator. D should then be viewed as the expected damage conditional on the regulator's expert information.

Still to simplify our modeling, we assume that the firm shares with the regulator his information on D.[21]

The damage D is drawn from a common knowledge cumulative distribution $H(\cdot)$ on the support $\mathcal{D} = [\underline{D}, \bar{D}]$ whose atomless and everywhere positive density is denoted by $h(\cdot)$. For technical reasons, we assume that the monotone hazard rate property, namely $\frac{d}{dD}\left(\frac{1-H(D)}{h(D)}\right) < 0$, holds. We denote by $E_D(\cdot|\cdot)$ the conditional expectation operator.

In the absence of any conflict of interests between Congress and the bureaucracy, granting full discretionary power to the regulator would certainly be optimal as we will confirm below. Discretion would then allow the regulator to tailor optimal regulatory policies to the realized damage without introducing any conflict with Congress. That such conflict might arise suggests instead that tools for ex ante control like, for instance, upper bounds on regulatory budgets and staff limits may be used to align incentives among public entities. We will be more explicit on the nature of those tools and how they apply as effective constraints on bureaucratic behavior in the sequel.

4 The Optimality of Discretionary Policies

As a useful benchmark, let us first consider the case where the firm is a deep-pocket and has always enough wealth to compensate victims for the amount of damage D done. For simplicity, we also assume that those potential damages are common knowledge and relax this assumption later on.

It is well-known that, in such contexts, even the non-verifiability of the firm's effort is not an obstacle to achieve efficiency. There are simple policy instruments that implement the efficient level of care without incurring any agency cost. A less often pointed out fact, although as important given our concerns, is that the distribution of payoffs between the firm and the rest of society does not depend on the regulator's objective.

[21] It turns out that relaxing this assumption would not modify any of our results. Assuming that D is the regulator's private information would introduce an informed principal problem in the relationship between the regulator and the firm. However, since the damage does not enter directly into the firm's payoff, we would be in a private values context. We know from Maskin and Tirole (1990) that private information would then not introduce any distortion with respect to the case where D is common knowledge when the principal is risk-neutral. A side-consequence of this common knowledge assumption is that we are implicitly focusing on an incomplete contracts environments where revelation mechanisms are not available.

To see that more formally, let us first write the firm's incentive constraint as:

$$e = \arg\max_{\tilde{e}} t - (1-\tilde{e})f - \psi(\tilde{e}) \quad \text{or} \quad f = \psi'(e). \tag{4}$$

The firm is active whenever it gets more than its reservation payoff that we will normalize at zero:

$$U = t - (1-e)f - \psi(e) \geq 0;$$

which, using (4) can be rewritten as

$$U = t - \psi'(e) + R(e) \geq 0, \tag{5}$$

where $R(e) = e\psi'(e) - \psi(e)$. The term $R(e)$ will be sometimes referred to as the liability rent in what follows. It satisfies $R(0) = R'(0) = 0$ with $R'(e) = e\psi''(e) > 0$ and $R''(e) = e\psi'''(e) + \psi''(e) \geq 0$.

Expressing the based payment t from the rest of society to the firm as a function of U, we may write the regulator's optimization problem as:

$$(\mathcal{P}_R): \quad \max_{\{U,e\}} S - D(1-e) - \psi(e) - (1-\alpha_R)U$$

$$\text{subject to (5).}$$

The solution to this problem is straightforward and summarized in the next proposition:

Proposition 1 *Absent liability constraints on the firm's side, the optimal risk regulation:*

- *Is independent of the regulator's preferences α_R;*
- *Implements the first-best level of effort $e^*(D)$ with a Pigovian fine equal to the damage*

$$D = f^*(D) = \psi'(e^*(D)); \tag{6}$$

- *Extracts all possible rent from the firm (i.e., (5) is binding)*

$$U^*(D) = 0.$$

This proposition confirms that the optimal regulation does not depend on the regulator's own preferences. As soon as the rent of the firm is viewed as costly but can still be fully extracted by the regulator, i.e., as soon as agency costs are zero, there is no real trade-off between efficiency and rent extraction. The regulatory policy perfectly fits with the policy that would be implemented by the Congress as well.

An immediate corollary is that the regulator's potential private information on D is not an issue either. The regulator would always use his expert knowledge to implement the efficient level of effort $e^*(D)$ and the correct distribution of payoffs between the firm and the rest of society. This leads us to the important property:

Proposition 2 *In the absence of any agency cost due to downstream moral hazard, leaving full discretion to the regulator is always optimal whatever his own preferences and those of Congress.*

In practice the regulator chooses a Pigovian fine $f^*(D) = D$ that makes the firm internalize the impact of its effort choice on the probability of a damage. A based payment $t^*(D)$ such that

$$t^*(D) = (1 - e^*(D))D + \psi(e^*(D))$$

covers the firm's expected losses and ensures participation.

5 Liability Rent and Endogenous Conflict between the Regulator and the Congress

Note that the policy $(f^*(D), t^*(D))$ we just highlighted fails to satisfy the firm's liability constraint when:

$$w + t^*(D) - f^*(D) = w - R(e^*(D)) < 0,$$

i.e., when the firm's has not enough assets to pay out from his own pocket the liability rent that induces the efficient effort. This is that case of a wealth constrained firm that is of interest for us in the sequel.

Let us now consider the more interesting and more realistic case where the firm is protected by limited liability, i.e., fines cannot exceed the sum of the firm's based payment and its initial wealth. The following liability constraint must be satisfied:

$$w + t - f \geq 0.$$

Using the definition of the firm's payoff, that constraint can be rewritten more compactly as:

$$U \geq R(e) - w. \tag{7}$$

5.1 Full Discretion Again

If the regulator is granted full discretion in choosing the regulatory policy, his problem could thus be written as:

$$(\mathcal{P}_R^L): \quad \max_{\{U,e\}} S - D(1-e) - \psi(e) - (1-\alpha_R)U$$
$$\text{subject to (5) and (7).}$$

From now on, we will instead assume that the firm has never enough wealth to cover the liability rent even if a second-best effort must be induced.[22] This means:

$$w < R(e^{SB}(\alpha_R, D)), \tag{8}$$

where $e^{SB}(\alpha_R, D)$ is defined as the solution to

$$D = \psi'(e^{SB}(\alpha_R, D)) + (1-\alpha_R)R'(e^{SB}(\alpha_R, D)). \tag{9}$$

We will come back later on the interpretation of (9). Turning to (8), this condition simply means that, to implement the effort level $e^{SB}(\alpha_R, D)$, the regulator would like the firm to pay out the liability rent $R(e)$ in case a harm occurs but this is impossible when (8) holds without hitting the firm's liability constraint. Alternatively, this also means that the limited liability constraint (7) is binding first. The firms earns a liability rent $R(e)$ which when greater than w, is enough to induce participation, i.e., (5) is implied by (7).[23]

Optimizing $(\mathcal{P}_R^L)$ leads to:

Proposition 3 *Under limited liability, the optimal regulation:*

[22]This is obviously always the case when $w = 0$.

[23]Of course, when w takes intermediate values it is the case that both the liability and the participation constraints are binding altogether. This leads to a second-best level of effort that solves $R(e^{SB}(w)) = w$. This case holds for $w \in [R(e^{SB}(\alpha_R, D)), R(e^*(D))]$. Those constrained regimes only depend indirectly of the regulator's preferences through the lower bound $e^{SB}(\alpha_R, D)$. This would make much of the effects that we highlight in this paper harder to uncover although it is not impossible to do so.

- *Depends on the regulator's preference* α_R*,*
- *Implements a second-best level of effort* $e^{SB}(\alpha_R, D)$ *that increases with* α_R*,*
- *Leaves to the firm a positive rent that increases with* α_R

$$U^{SB}(\alpha_R, D) = R(e^{SB}(\alpha_R, D)) - w > 0.$$

Under limited liability, optimal regulation entails agency costs. There is now a trade-off between extracting the firm's liability rent and achieving efficiency. The first of these objectives calls for distorting downward the firm's effort, contradicting thereby the second objective. More precisely, with limited liability, the firm's punishment in case it causes some harm is limited and the only way to provide incentives is to increase the firm's based payment t in case no such harm arises. Of course, this requires now leaving a rent $R(e) - w$ to the firm which is viewed as socially costly, even by the regulator, since $\alpha_R < 1$. Reducing this rent requires reducing the power and incentives. Effort is downward distorted as shown on (9).

Importantly, a regulator who puts a greater weight on the firm's profit in his objective function chooses a lower downward distortion of effort and let the firm enjoy a greater liability rent. In particular, because the regulator is "pro-firm" ($\alpha_C < \alpha_R$), he excessively tilts the trade-off between rent-extraction and efficiency towards efficiency, leaving too much rent to the firm.

Because the agency problem downstream introduces now a true trade-off between efficiency and rent extraction, it creates a bias between the preferences of Congress and the regulator. The agency problem trickles up the hierarchy: Although the benefit of leaving discretion to the regulator is to have regulatory policy tailored to the regulator's expertise on damage, the cost is that the regulator may tilt regulatory policies excessively in favor of the firm.

5.2 Ex Ante Optimal Constraints on Regulatory Agency

To better align the regulator's objectives with his own in this second-best world, Congress must design ex ante rules that might put constraints on the regulator's discretion.

To understand this control, consider first the case where an exogenous constraint on the firm's possible fine f is imposed by Congress.

Suppose that Congress forces the regulator to choose a fixed fine f_C such that:

$$f_C = \psi'(e_C) \text{ where } E_D(D) = \psi'(e_C) + (1 - \alpha_C)R'(e_C). \tag{10}$$

This fine is independent of the realized level of damage. This is an ex ante rule what would be chosen by Congress itself in the absence of any expert information on the amount of damages. It is thus a non-discretionary policy and, if such policy was imposed on the regulator, he would have no choice except to abide to that rule. The benefit of that rule is of course that the rent/efficiency trade-off is evaluated according to Congress's preferences although now local expertise is always lost.

More generally, we are interested at this stage in describing the whole set of *incentive mechanisms* that limit the bureaucrat's discretion and still may make use of his expertise, at least over some ranges of possible realizations of D. In looking for such a characterization, we follow Holmström (1984), Armstrong (1994), Melumad and Shibano (1991), Martimort and Semenov (2006, 2008) and Alonso and Matouscheck (2008). These authors model delegation as a mechanism design problem in the absence of any monetary transfers between Congress and the regulator. This approach helps to derive the optimal ex ante restriction on what the regulator can do without any ad hoc restriction.

Such direct mechanism can a priori be viewed as a collection of fines $\{f(\hat{D})\}_{\hat{D}\in[\underline{D},\bar{D}]}$ contingent on the regulator's announcement $\hat{D}$ on the level of possible damages.[24] From the Revelation Principle, there is no loss of generality in considering such mechanisms which are truthful. Alternatively, one can view such mechanisms as stipulating a range of possible fines from which the regulator can choose from. This interpretation in terms of *delegation sets*, i.e., in terms of the range of the mechanisms $\{f(\hat{D})\}_{\hat{D}\in\mathcal{D}}$[25] stresses the role that Congress plays in restricting ex ante the possible options available to the regulator.

Nevertheless, it is worth pointing out that two restrictions are made with respect to the largest possible class of mechanisms. First, and for the sake of realism we focus on deterministic mechanisms[26] Our second restriction, again made for the sake of simpli-

[24]Note that, under limited liability, the base payment is function of the fine through the condition $t = f - w$. So, everything happens as if Congress was leaving to the agency the choice of a particular pair of incentive payments for the firm along a segment on that line.

[25]This interpretation is based on the so-called Taxation Principle that mirrors the Revelation Principle and replaces the direct revelation mechanisms by an indirect one where the agent has to choose within the set of relevant options that the corresponding direct revelation mechanism was offering.

[26]Congress is not allowed to offer possible lotteries of fines among which the regulator could choose from. Kovac and Mylovanov (2007) analyzed conditions under which such stochastic mechanisms are

fying the analysis, consists in focusing on continuous mechanisms (or alternatively on delegation sets which are connected). As we will see below those mechanisms have a nice characterization that is quite tractable.[27]

Alternatively, given the one-to-one mapping between fines and effort that comes out the firm's incentive constraint (4), we may as well consider that those mechanisms stipulate what effort the regulator should implement in response to his private information. We will thus denote accordingly such mechanism as $\{e(\hat{D})\}_{\hat{D}\in[\underline{D},\bar{D}]}$.

Given that he knows the level of damage D, implementing effort $e(\hat{D})$ yields the following payoff to the regulator:

$$W_R(\hat{D}, D) = -D(1 - e(\hat{D})) - \psi(e(\hat{D})) - (1 - \alpha)R(e(\hat{D})).$$

Incentive compatibility constraints necessary to induce truthtelling by the regulator can thus be written as:

$$D \in \arg\max_{\hat{D}\in\mathcal{D}} W_R(\hat{D}, D). \tag{11}$$

Standard revealed preferences arguments show that:

Lemma 1 *Any incentive compatible mechanism* $\{e(\hat{D})\}_{\hat{D}\in\mathcal{D}}$ *is such that:*

- $e(D)$ *is monotonically increasing in* D *and is thus almost everywhere differentiable with at any differentiability point*

$$\dot{e}(D) \geq 0; \tag{12}$$

- *At any differentiability point of* $e(D)$*, we have*

$$\dot{e}(D)\,(D - \psi'(e(D)) - (1 - \alpha_R)R'(e(D))) = 0. \tag{13}$$

not optimal in a models with quadratic payoffs. Laffont and Martimort (2002) argued that stochastic mechanisms require the ability to commit to use a public randomizing device which could be manipulated making those mechanisms less credible than deterministic ones.

[27]Melumad and Shibano (1991), Martimort and Semenov (2006), Alonso and Matouscheck (2008) and Kovac and Mylovanov (2007) all provided conditions on distributions and utility functions ensuring continuity of the optimal mechanism.

The monotonicity condition (12) simply means that, as the level of damage increases, the fines and the implemented effort should also increase. This is a quite natural condition that is for instance satisfied by the full discretion outcome $e^{SB}(\alpha_R, D)$.

The first-order condition for the regulator's incentive problem (13) simply means that the optimal fine is either flat and independent of the damage levels or corresponds to the regulator's ideal policy. In that latter case, the regulator uses his discretion to tailor the fine to the level of damages. Given the monotonicity of effort, the characterization of continuous mechanisms is straightforward:

Lemma 2 *Any implementable policy $\{e(D)\}_{D\in\mathcal{D}}$ that is continuous is of the form:*

$$e(D) = \min\left\{\max\{e^{SB}(\alpha_R, D), e^{SB}(\alpha_R, D_1)\}, e^{SB}(\alpha_R, D_2)\}\right\}, \tag{14}$$

where $\underline{D} \leq D_1 \leq D_2 \leq \bar{D}$.

This characterization is extremely useful because it shows that the amount of discretion left to the regulator is bounded above by a cap on fines, $f^{SB}(\alpha_R, D_2) = \psi'(e^{SB}(\alpha_R, D_2)))$, and maybe below by a floor, $f^{SB}(\alpha_R, D_1) = \psi'(e^{SB}(\alpha_R, D_1))$. Within that interval, the regulator has full discretion in setting up the fines according to his own preferences.

To provide more intuition on the limits to the regulator's discretion, we now investigate whether the regulator would have any incentives to manipulate his expert information on damage if the optimal policy $e^{SB}(\alpha_C, D)$ that would be directly chosen by Congress if it was aware of the realization of the damages was implemented. We find:

$$\begin{aligned}\frac{\partial}{\partial \hat{D}} W_R(\hat{D}, D)\Big|_{\hat{D}=D} &= \frac{\partial e^{SB}}{\partial D}(\alpha_C, \hat{D})\left(D - \psi'(e^{SB}(\alpha_C, \hat{D})) - (1-\alpha_C)R'(e^{SB}(\alpha_C, \hat{D}))\right)\Big|_{\hat{D}=D} \\ &= \Delta\alpha \frac{\partial e^{SB}}{\partial D}(\alpha_C, D) R'(e^{SB}(\alpha_C, D)) > 0.\end{aligned}$$

Hence, the mechanism $\{e^{SB}(\alpha_C, D)\}_{D\in\mathcal{D}}$ is not incentive compatible: The regulator finds it always optimal to exaggerate damage. By doing so, the "pro-firm" regulator chooses higher levels of effort, and increases the firm's rent more than what Congress would do.

This discussion already suggests that there is no reason to fix a floor on fines since the regulator has never any incentive to underestimate damages. Instead, putting a cap on those fines certainly helps aligning the objectives of the different layers.[28] Therefore, the

[28]This is confirmed in the next proposition with a formal proof in the Appendix.

optimal mechanism is of the form $e(D) = \min\{e^{SB}(\alpha_R, D), e^{SB}(\alpha_R, D^*)\}$ where the level of discretion D^* is the optimization variable available to Congress.

Under asymmetric information on D, Congress's optimization problem can be written as:

$$(\mathcal{P}_R^{SB}): \quad \max_{D^*} S - E_D(D(1-e(D)) + \psi(e(D)) + (1-\alpha_C)R(e(D)))$$
$$\text{where } e(D) = \min\{e^{SB}(\alpha_R, D), e^{SB}(\alpha_R, D^*)\}.$$

Optimizing $(\mathcal{P}_R^{SB})$ finally leads to:

Proposition 4 *The Congress chooses optimally a cap $e^{SB}(\alpha_R, D^*(\alpha_R))$ on the effort that the regulator may implement where $D^*(\alpha_R) \in (\underline{D}, \bar{D})$ is uniquely defined as the solution to:*

$$E_D(D|D \geq D^*(\alpha_R)) = \psi'(e_R(D^*(\alpha_R))) + (1-\alpha_C)R'(e_R(D^*(\alpha_R))) \tag{15}$$

when $e^{SB}(\alpha_R, \underline{D}) \leq e_C \leq e^{SB}(\alpha_R, \bar{D})$.

- *The regulator is not constrained by the cap and chooses $e^{SB}(\alpha_R, D)$ if and only if $D \in [\underline{D}, D^*(\alpha_R)]$.*
- *If $e^{SB}(\alpha_R, \underline{D}) > e_C$, the regulator has no discretion left and implements always the effort e_C which is ex ante socially optimal from the Congress' viewpoint.*
- *If $e^{SB}(\alpha_R, \underline{D}) \leq e_C$, the regulator has always some discretion but neither full discretion.*

The intuition behind this proposition is straightforward. Putting a cap on fines better aligns the regulator's choice with the ideal policy for Congress.

Once the cap is hit, i.e., when the level of damages is high enough and reaches $D^*(\alpha_R)$, the optimal policy is then the regulator's ideal policy at $D^*(\alpha_R)$, namely $e^{SB}(\alpha_R, D^*(\alpha_R))$. It is of course higher than the ideal policy $e^{SB}(\alpha_C, D^*(\alpha_R))$ that Congress would choose at that point. However, such effort level comes closer to $e^{SB}(\alpha_C, D)$ when D increases to the point where $e^{SB}(\alpha_R, D^*(\alpha_R))$ might be too low compared with $e^{SB}(\alpha_C, \bar{D})$. That optimal level of discretion $D^*(\alpha_R)$ is then optimally chosen to trade off the distortions of having an effort level $e^{SB}(\alpha_R, D^*(\alpha_R))$ which is too low for D close but above $D^*(\alpha_R)$ and which is too high for D close but below $\bar{D}$.

A fully rigid rule at e_C only arises when there is enough conflict of interests between the agency and Congress. For lower levels of the conflict, giving discretion to the agency over the upper tail of the distribution of damages is never optimal. Indeed, given that necessarily $e^{SB}(\alpha_R, \bar{D}) > e^{SB}(\alpha_C, \bar{D})$, it is always optimal to cap the level of effort in the neighborhood of $\bar{D}$ to bring it closer to the Congress' preferences.

• **Implementation:** The optimal solution can be implemented by simply imposing a cap $f^{SB}(D^*(\alpha_R)) = \psi'(e^{SB}(\alpha_R, D^*(\alpha_R)))$ on the amount of fines that the regulator could choose. This is precisely the case for two examples given in the Introduction, the regulation of nuclear operator and oil transportation, but this is a more pervasive feature of any environmental enforcement.

Another possible implementation of the optimal mechanism consits in leaving to the agency the choice a fine from the set $[\psi'(e^{SB}(\alpha_R, \underline{D}))), \psi'(e^{SB}(\alpha_R, D^*(\alpha_R)))]$. This leads us to a nice interpretation of how "vague" the agency's mandate is. A vague mandate corresponds to lots of freedom for the agency, which typically arises when $e^{SB}(\alpha_R, \underline{D})$ and $e^{SB}(\alpha_R, D^*(\alpha_R))$ are sufficiently far apart. Instead, a strict mandate corresponds to such smaller intervals.

5.3 Comparative Statics

To sharpen intuition, consider the case of a quadratic disutility function, i.e., $\psi(e) = \frac{\lambda e^2}{2}$ for some $\lambda > 0$ large enough so that optimal efforts remain within the interval $[0, 1]$. Then, it is straightforward to check that $e^{SB}(\alpha_R, D) = \frac{D}{\lambda(2-\alpha_R)}$ and (15) yields

$$E_D(D|D \geq D^*(\alpha_R)) = \lambda(2 - \alpha_C)e^{SB}(\alpha_R, D^*(\alpha_R))(D^*(\alpha_R)) = \frac{2 - \alpha_C}{2 - \alpha_R} D^*(\alpha_R).$$

Putting it differently, we get the more compact formula:

$$E_D(D|D \geq D^*(\alpha_R)) - D^*(\alpha_R) = \frac{\Delta\alpha}{2 - \alpha_R} D^*(\alpha_R). \quad (16)$$

• **"Ally Principle"**: Form this, we immediately recover the so-called *"Ally Principle"*, i.e., all else being equal, there is more discretion left to the agency as its objectives are closer to those of Congress:

Corollary 1 *Assume a quadratic disutility function* ($\psi(e) = \frac{\lambda e^2}{2}$). *An increase in the conflict of interests between Congress and the regulator (i.e.,* $\Delta\alpha$ *becoming greater) reduces the regulator's discretion (i.e.,* $D^*(\alpha_R)$ *diminishes).*

This result also suggests that tougher rules are imposed on agencies in periods of divided governments where the preferences of Congress and the Executive are further apart one from the other, and in parliamentary systems where compromising party strategies may lead to more convergence between those two branches. Beyond the case of risk regulation which is our concern in this paper, those facts have more generally received significant empirical support in the political science literature.[29]

• **Comparison of information structures:** It is also interesting to investigate how changes in the distribution of damages affect the degree of discretion left to the agency.

Front-loading: In this respect, say that a distribution $H_1(\cdot)$ is *more "front-loaded"* than a distribution $H_2(\cdot)$ if and only if:

$$\frac{1}{1-H_1(D)}\int_D^{\bar{D}} xh_1(x)dx < \frac{1}{1-H_2(D)}\int_D^{\bar{D}} xh_2(x)dx \text{ for all } D \in [\underline{D}, \bar{D}) \text{ (with equality at } \bar{D}). \tag{17}$$

This inequality simply means that the conditional expectations of the damages over the upper tail $[D, \bar{D}]$ is always greater with $H_2(\cdot)$ than with $H_1(\cdot)$.[30] Intuitively, this means that $H_1(\cdot)$ puts more mass around the lower tail of the distribution than $H_2(\cdot)$.

Corollary 2 *Assume a quadratic disutility function* ($\psi(e) = \frac{\lambda e^2}{2}$). *The regulator has more discretion when* D *is drawn from the distribution* $H_2(\cdot)$ *than when it is drawn from the distribution* $H_1(\cdot)$ *(i.e.,* $D^*(\alpha_R)$ *increases) if* $H_1(\cdot)$ *is more front-loaded than* $H_2(\cdot)$.

Corollary 2 shows that this is not uncertainty per se that affects the level of discretion left to the agency and makes it more likely to have more discretion. Instead, the amount of discretion is linked to the fine properties of conditional expectations. A more front-loaded distribution makes it less likely that damages are high enough. This means that any "large" reports on possible damages is interpreted by Congress as coming from a regulator who is very likely to exaggerate those damages. Hence, tougher rules should be implemented and less discretion should be left to the agency in such case.

[29] See among others Wood and Bohte (2004), Epstein and O'Halloran (1994), and Huber and Shipan (2002).

[30] In particular, the average damage is greater with distribution $H_2(\cdot)$ than with distribution $H_1(\cdot)$.

This result suggests that domains where risks are relatively minor "on average" should be mostly ruled by norms whereas, in domains where risks are more significant, agencies should have more discretionary power on lower tails.

More uncertainty in the sense of Blackwell: Let us now investigate the impact of scientific progress on risk regulation. This question is particularly relevant in the case of GMOs for instance where little is know on the consequences of allowing some products at the time of enacting regulations but more knowledge on the distribution of potential damages will be known as we go.

We model the arrival of scientific knowledge as a decrease in uncertainty the sense of Blackwell. Consider thus the case where Congress observes K signals on the possible distribution of damages. Denote also by $H_k(\cdot)$ (resp. $h_k(\cdot)$) the cumulative distribution on $[\underline{D}, \bar{D}]$ (resp. density) corresponding to signal $k \in \{1, .., K\}$ and let x_k be the positive probability that signal k realizes with $\sum_{k=1}^{K} x_k = 1$. From an ex ante viewpoint, i.e., before the arrival of scientific knowledge, we have $H(D) = \sum_{k=1}^{K} H_k(D)$ (resp. $h(D) = \sum_{k=1}^{K} h_k(D)$).

Ex post, i.e., once knowledge gets publicly revealed , the amount of discretion $D_k^*(\alpha_R)$ left to the regulator in case signal k realizes is obtained from (16) as:

$$\frac{1}{1 - H_k(D_k^*)} \int_{D_k^*(\alpha_R)}^{\bar{D}} Dh_k(D)dD - D_k^*(\alpha_R) = \frac{\Delta\alpha}{2 - \alpha_R} D_k^*(\alpha_R).$$

For the case of exponential distributions where $H_k(D) = 1 - exp(-\mu_k D)$ for some $\mu_k > 0$ (resp. $h_k(D) = \mu_k exp(-\mu_k D)$), we find that:

$$\mu_k D_k^* = \frac{2 - \alpha_R}{\Delta\alpha}. \tag{18}$$

Instead, without the signals, the amount of discretion $D^*(\alpha_R)$ left solves (with $E_k(\cdot)$ denoting the expectation operator with respect to σ):

$$\frac{1}{1 - E_k(H_k(D^*(\alpha_R)))} \int_{D^*(\alpha_R)}^{\bar{D}} DE_k(h_k(D))dD - D^*(\alpha_R) = \frac{\Delta\alpha}{2 - \alpha_R} D^*(\alpha_R)$$

or

$$\frac{E_k\left(\frac{exp(-\mu_k D^*(\alpha_R))}{\mu_k}\right)}{E_k\left(exp(-\mu_k D^*(\alpha_R))\right)} = \frac{\Delta\alpha}{2 - \alpha_R} D^*(\alpha_R).$$

This yields immediately:

Corollary 3 *Assume a quadratic disutility function ($\psi(e) = \frac{\lambda e^2}{2}$) and that distributions are exponential. More uncertainty the sense of Blackwell increases the regulator's discretion (on average):*

$$D^*(\alpha_R) \geq E_k\left(D^*_k(\alpha_R)\right). \tag{19}$$

The rough intuition for this result comes from observing that the more uncertain distribution $H(\cdot)$ has higher conditional expectations on the upper tail than the average conditional expectations obtained when knowledge is revealed.

Coming back on our GMOs example, this result suggests that higher powered incentives and more discretion should arise at the inception of those regulation but, as time goes on, tighter regulations will be enforced "on average" as knowledge on the kind of risks run with those products evolve.

An often-found argument in the political science literature[31] is that more *uncertainty* in the regulatory environment makes it more likely to delegate discretionary power to the agency but are a bit silent on what does this "more uncertainty" means. Altogether Corollaries 2 and 3 confirm this view and make it a bit more precise what can be meant to have more uncertainty.

6 Endogenous Distributions of Damages

The previous analysis has stressed the impact that the properties of the distribution of damages have on the amount of discretion left to the agency. These distributions are to a large extent endogenous and depend on some technological choices that may be undertaken by the firm. This endogeneity in turn affects how much discretion is left to the agency.

To understand how it is so, suppose now that the firm can affect the distribution of the damage D by making some technological choice, or investment, I which is non-verifiable. Denote by $H(\cdot|I)$ this distribution function, by $B(I)$ the net return on that technological choice (including the cost of investment) and assume that $B(\cdot)$ is concave on $\mathbb{R}$ with an interior maximum I^*.

We will also assume that a greater investment makes it "more likely" that damages are

[31]See Epstein and O'Halloran (1994, 1999) and Bawn (1995) for instance.

high in two respects. First, a greater investment makes distributions be less front-loaded, which generalizing (17) means

$$\frac{\partial}{\partial I}\left(E_{\tilde{D}}(\tilde{D}|D,I)\right) > 0 \text{ for all } (D,I). \tag{20}$$

Second, a greater investment also shifts up the distribution of damages in the sense of first-order stochastic dominance

$$H_I(D|I) < 0 \text{ for all } (D,I), \tag{21}$$

If this ex ante investment was contractible, the socially optimal one would be chosen by the regulator at I^* such that $B'(I^*) = 0$ irrespectively of his own preferences. However, once this investment is nonverifiable, the firm chooses I to maximize its overall payoff including the net return on investment and the expected rent that it gets from limited liability taking into account the incentive schemes it will receive from the regulator. Constraints on regulation, and more specifically how much discretion is left to the agency, are chosen taking into account conjectures on the investment level (which at equilibrium are correct). This leads us to the simultaneous characterization of the investment choice and the cap on regulation as follows:

$$I^{SB} = \arg\max_I \int_{\underline{D}}^{\bar{D}} R(\min(e^{SB}(\alpha_R, D), e^{SB}(\alpha_R, D^*(\alpha_R))))dH(D|I) + B(I)$$

where $e^{SB}(\alpha_R, D^*(\alpha_R))$ solves now

$$E_D(D|D \geq D^*(\alpha_R), I^{SB}) = \psi'(e_R(D^*(\alpha_R))) + (1-\alpha_C)R'(e_R(D^*(\alpha_R)))$$

The first-order condition for the firm's problem can then be written as:

$$\int_{\underline{D}}^{\bar{D}} R(\min(e^{SB}(\alpha_R, D), e^{SB}(\alpha_R, D^*(\alpha_R))))dH_I(D|I^{SB}) + B'(I^{SB}) = 0.$$

Integrating by parts and taking into account that the effort level is independent of D over the interval $[D^*(\alpha_R), \bar{D}]$ yields

$$-\int_{\underline{D}}^{D^*(\alpha_R)} R'(e^{SB}(\alpha_R, D))\frac{\partial e^{SB}}{\partial D}(\alpha_R, D)H_I(D|I^{SB})dD + B'(I^{SB}) = 0.$$

Clearly, we immediately get from there that investment is excessive from a social viewpoint ($I^{SB} > I^*$) as soon as $D^*(\alpha_R) > \underline{D}$, i.e., as soon as the regulator has some discretion. Intuitively, when the investment is nonverifiable, the firm not only cares about the impact of its investment on the direct benefit but also on the expected liability rent it may withdraw. As to the first impact, even if I is nonverifiable, the firm's private incentives are aligned with the socially optimal ones. Instead, the impact on the expected rent is novel. The firm cares indeed on the whole range of values of D where changes in the distribution affect its expected rent. This cannot be the case on the upper tail of the distribution ($D \geq D^*(\alpha_R)$) where the regulatory policy follows a rule independent of D and there is no way to affect the firm's rent there. This is instead the case on the lower tail ($D \leq D^*(\alpha_R)$) where the agency has discretionary power. On this range, increasing I makes it more likely that higher values of D realizes what, in turn, means higher effort and higher rents. This rent effect pushes investment up.

The important point to notice is that, when taking as given this higher investment and thus the corresponding shift towards a distribution which is less front-loaded, Congress leaves *more* discretion to the agency as it follows immediately from Corollary 2.[32]

Proposition 5 *Assume a quadratic disutility function ($\psi(e) = \frac{\lambda e^2}{2}$) and that the firm's ex ante investment satisfies conditions (20) and (21). The regulator has more discretion when the firm's investment is non-verifiable than when it is.*

7 Political Uncertainty and Asymmetric Information on the Regulator's Preferences

Ex ante constraints on regulators may be designed in a context of significant uncertainty on the preferences of those agencies. This uncertainty may be exogenous and linked to the intrinsic motivation of the bureaucrats.

This uncertainty can be endogenous to the political process. This is the case when it is induced by random changes in the identity of the Executive in office which, through the appointment process, may also trigger further changes in the identity of the regulatory agency's head (or in the composition of its Executive Committee by reshuffling majority).

[32] A word of caution should be made here. Assume on the contrary that Congress moves thus and may choose the level of discretion left to the agency before the firm's investment. Then, Congress would had a motive to reduce the agency's discretion to better align the firm's incentives to invest with the socially optimal ones.

To model such settings, we assume that, at the time of designing ex ante constraints on the agency, α_R is viewed as random by the Congress with α_R being distributed on $[\alpha_C, 1]$ so that even the agency the less eager to favor the firm still has more pronounced pro-firm preferences than Congress but still liability rents remain always costly. Denote $E_\alpha(\cdot)$ the corresponding expectation operator with respect to the density $g(\cdot)$ and by $G(\cdot)$ the cumulative distribution.

Now, the amount of discretion left to the agency must take into account uncertainty on the exact policy it would follow in case ex ante rules do not bind. The question we investigate in this section is to what extent this political uncertainty gets translated into the amount of discretion left to the agency.

Formally, and in full generality, a deterministic incentive mechanism must now induce the regulator to reveal truthfully all his information. Such mechanism writes as $\{f(\hat{\alpha}, \hat{D})\}_{\{\hat{\alpha}\in[\underline{\alpha},\bar{\alpha}],\hat{D}\in[\underline{D},\bar{D}]\}}$ (or equivalently using (4) an effort level $\{e(\hat{\alpha}, \hat{D})\}_{\{\hat{\alpha}\in[\underline{\alpha},\bar{\alpha}],\hat{D}\in[\underline{D},\bar{D}]\}}$) and specifies a level of fines as a function of the regulator's report on the level of damage he privately observes and his report on his preferences.

Incentive compatibility constraints necessary to induce truthtelling can now be written as:

$$(\alpha, D) \in \arg\max_{(\hat{\alpha},\hat{D})} -D(1 - e((\hat{\alpha}, \hat{D})) - \psi(e(\hat{\alpha}, \hat{D})) - (1-\alpha)R(e(\hat{\alpha}, \hat{D})).$$

Standard revealed preferences arguments show that:

Lemma 3 *Any incentive compatible mechanism* $\{e(\hat{\alpha}, \hat{D})\}_{\{\hat{\alpha}\in[\underline{\alpha},\bar{\alpha}],\hat{D}\in[\underline{D},\bar{D}]\}}$ *is such that:*

- $e(\cdot)$ *is monotonically increasing in* α *and* D *and is thus almost everywhere differentiable with at any differentiability point*

$$\frac{\partial e}{\partial \alpha}(\alpha, D) \geq 0 \text{ and } \frac{\partial e}{\partial D}(\alpha, D) \geq 0; \tag{22}$$

- *At any differentiability point of* $e(\alpha, D)$, *we have*

$$\frac{\partial e}{\partial \alpha}(\alpha, D)\,(D - \psi'(e(\alpha, D)) - (1-\alpha)R'(e(\alpha, D))) = 0. \tag{23}$$

$$\frac{\partial e}{\partial D}(\alpha, D)\,(D - \psi'(e(\alpha, D)) - (1-\alpha)R'(e(\alpha, D))) = 0. \tag{24}$$

The incentive compatibility conditions (23) and (24) when taken altogether show that the regulator either choose his most preferred policy $e^{SB}(\alpha, D)$ or is forced to choose an effort level independent of the level of damage and of his own preferences.

Following, this observation, it is straightforward than the possible incentive mechanisms leave again discretion when the effort level that the regulator would like to implement $e^{SB}(\alpha, D)$ is below some threshold e^*.[33] This is either because D is small enough or because α itself is low enough, i.e., because the regulator's preferences are close enough to those of Congress.

We can write Congress' problem of choosing an optimal cap e^* as:

$$(\mathcal{P}_R^{AI}): \quad \max_{e^*} S - E_{(D,\alpha)}(D(1-e(\alpha,D)) + \psi(e(\alpha,D)) + (1-\alpha_C)R(e(\alpha,D)))$$

$$\text{where } e(\alpha, D) = \min\{e^{SB}(\alpha, D), e^*\}.$$

To get sharp predictions, let us assume again a quadratic disutility function ($\psi(e) = \frac{\lambda e^2}{2}$). The optimal cap e^{AI} solves:[34]

$$\int_{\lambda e^{AI}}^{\bar{D}} (D - (2-\alpha_C)\lambda e^{AI}) \left(1 - G\left(2 - \frac{D}{\lambda e^{AI}}\right)\right) h(D)dD = 0. \tag{25}$$

We are particularly interested in understanding how *"more uncertainty"* on the regulator's preferences affect the optimal degree of discretion. To investigate such issues, let us consider a "generator", i.e., a cumulative distribution $\chi(x)$ having for support the interval $[-1, 1]$ such that $\chi(0) = 0$, $\chi(1) = 1$ with a density function $\varsigma(x) = \chi'(x)$ which is centered at 0, i.e., $\int_{[-1,1]} x\varsigma(x)dx = 0$. Denote also $\sigma_2 = \int_{[-1,1]} x^2\varsigma(x)dx$ the variance of this generator.

From this generator, one can construct a family of distributions for α which are centered around $\alpha_R \in (\alpha_C, 1)$ with the cumulative distribution functions:

$$G_\epsilon(\alpha) = \chi\left(\frac{\alpha - \alpha_R + \epsilon}{\epsilon}\right).$$

As ϵ converges to zero, these distributions put all mass on a shrinking interval around α_R. "More uncertainty" on the regulator's preferences can then be modeled as an increase

[33] The proof that a setting floor is never optimal is straightforward but computationally heavy.

[34] See the Appendix for details.

in ϵ. Denote then by $e^{AI}(\epsilon)$ the optimal cap corresponding to the distribution $G_\epsilon(\cdot)$. In particular, we already know from Section 5.3 that $e^{SB}(0) = \frac{D^*(\alpha_R)}{\lambda(2-\alpha_R)}$.

The following proposition provides an approximation of the optimal cap as ϵ goes small.

Proposition 6 *The amount of uncertainty on the regulator's preferences has only at most a second-order impact on the degree of discretion left to the regulator. With an exponential distribution on* $[0, +\infty)$ *having mean* $\frac{1}{\mu}$*, the following approximation holds*

$$e^{AI}(\epsilon) = e^{AI}(0) - \frac{\epsilon^2(7 - 3\sigma^2)}{4\lambda\mu(2 - \alpha_C)\Delta\alpha^2} \tag{26}$$

When the generator has little variance (σ^2 is small enough[35]), which means that the distribution of uncertainty on the regulator's preferences has more mass around α_R than on the extreme of the interval $[\alpha_R - \epsilon, \alpha_R + \epsilon]$, increasing uncertainty on the regulator's preferences decreases the regulatory cap. When the generator has more variance (σ^2 is high enough), increasing uncertainty on the regulator's preferences increases instead the regulatory cap and makes discretion more attractive. This case is more likely in political systems where political fluctuations on the identity of the Executive branch are more pronounced. As a corollary, consider independent agencies, or agencies which are headed by Committees whose composition is only partially modified by newly elected Executives. Such agencies are certainly characterized by little fluctuations in preferences and discretion is certainly reduced accordingly.

Similarly, as time goes on, the preferences of the agency may be, at least partially, revealed by the past history of its actions (σ^2 decreases). When political uncertainty decreases over time, our model predicts that the agency should get less discretion. This suggests also that older agencies should have less freedom in setting regulatory policies than newly established ones.

8 Strategic Appointment

So far, we have assumed that the Executive and the agency had preferences that were perfectly aligned. Moreover, the last section has shown how Congress may enact regulations when anticipating changes or at least some uncertainty on the identity of future

[35]In the case where $\chi(\cdot)$ is uniform, $\sigma^2 = \frac{1}{3}$.

political principals in the Executive branch. Politics is often more of an ongoing process with Congress and the Executive reacting each in turn to the other move. In this section, we take the alternative view and give the Executive the lead in the appointment process and show how that move can be used strategically.[36] Given the restriction on the agency's discretion induced by Congress's rules, an important question is to ascertain whether the Executive can appoint a regulator whose preferences can be chosen to relax that constraint.

Indeed, we show below that the Executive prefers choosing a regulator whose preferences are closer to those of Congress so that its enhanced discretion favors the firm and pushes the regulatory outcome towards the Executive's ideal point.

To analyze the strategic leverage that the Executive has through the appointment process, consider a setting where the Executive's preferences α_E are more "pro-firm" than Congress, namely $\alpha_C < \alpha_E < 1$. Anticipating the choice of Congress on the level of discretion left to the regulator, the Executive acts as a Stackelberg leader when choosing the regulator's preferences.

Proposition 7 *Assume that the Executive's preferences α_E are more "pro-firm" than Congress, i.e., $\alpha_C < \alpha_E < 1$. Then, the Executive chooses a regulator with preferences closer to those of Congress than his own: $\alpha_C < \alpha_R < \alpha_E$.*

This result is remarkable. The Executive chooses to strategically delegate to bureaucrats having objectives better aligned with those of Congress than his own. This doing induces a softer stance on the regulator. This leaves more discretion to the regulator and commands higher rent for the regulated firm which in turn favors the Executive's objective.

Formally, choosing a regulator who is a little bit less eager than the Executive to please the firm has only a second-order impact on the Executive's expected payoff when damages are low enough and the regulator has full discretion in setting up a regulatory policy. However, reducing α_R aligns also somewhat Congress with the agency's objectives and relaxes by a first-order term the cap on possible fines that is hit once damages are large enough.

[36] A typical example is given by nominations at the head of the EPA in the U.S. This is a Federal agency under the control of the Presidency but which implements environmental regulations enacted by Congress.

This result predicts therefore that regulation reflects, at equilibrium, the desire of the different public bodies involved in a rather accommodating manner.

9 Conclusion

This paper has shown how agency problems may propagate along the regulatory hierarchy. Downstream regulation of the firm in a moral hazard context justifies giving up liability rent to induce safety care. However, the "pro-firm" biased regulatory agency and Congress may be in conflict on the amount of that rent. This upstream conflict leads Congress to put ex ante constraints on what the agency can do even though this agency could tailor the optimal regulation to the particular expert information it has on possible damage that the firm generates when it misbehaves. We have shown that the trade-off between rules and discretion that arises in such contexts depends on economic (properties distribution of risks) as well as political factors. Optimal regulations may look like rigid rules making no use of the agency' expert information and cap of what the agency can implement are pervasive. Moreover, in many respects, more uncertainty in the underlying environment be it on the economic or political side suggests goes in the direction of giving more discretion to the agency.

Those results could be extended along several lines. First, consider the case of an agency which is less "pro-firm" than Congress. This can be for instance the case when the median voter in Congress comes from a district which is much concerned by the firm's industrial activity. The problem is now to induce the agency to adopt soft regulations that leave more rent than what Congress would like. Still, there is a trade-off between rules and discretion but now it leads to putting a floor on the fine that the firm might pay in case a damage arises. Because it has incentives to pretend damages are low enough to induce low-powered regulations, the agency has discretion only on the upper tail of the distribution of those damages. On the lower tail instead, a rigid regulation is implemented.[37] Except for this reversal in the nature of the ex ante control and for the associated comparative

[37] When $\alpha_R < \alpha_C$, it is straightforward to check that the optimal cut-off $D^*(\alpha_R)$ below which the rigid rule binds solves:

$$E_D(D|D \leq D^*(\alpha_R)) = \psi'(e_R(D^*(\alpha_R))) + (1-\alpha_C)R'(e_R(D^*(\alpha_R)))$$

when $e^{SB}(\alpha_R, \bar{D}) \geq e_C \leq e^{SB}(\alpha_R, \bar{D})$.

statics,[38] all our other results go through: The "Ally Principle" still holds; it is still true that firms may want to choose technology that shifts the distribution of damages on areas where the regulator has some discretion; again, the Executive strategically chooses a regulator whose preferences are close to Congress.

Less trivial extensions of our framework should also investigate how *ex post* devices may help to solve the upstream agency problem between Congress and the agency. The joint use of ex post monitoring devices and ex ante controls is a recurring theme of the political science literature. Direct oversights by congressional committees, regulatory budget reviews and costly audits[39] by specialized agencies such as the General Accounting Office, and fire-alarms by interest groups are all examples of such devices that may help relax the agency's incentive constraints and improve the ex ante trade-off between rules and discretion. It would be important to introduce such ingredients into our analysis.

Another important extension of our framework would be to consider other agency problems downstream. Most of the *New Economics of Regulation* has been developed in a framework where this is adverse selection downstream that generates the regulated firm's information rent. Nevertheless, we conjecture that the lessons of this paper would go through in such environment. Asymmetric information downstream generates a rent/efficiency trade-off that may be appreciated differently by the agency and Congress. Again rules might be quite attractive.

These are alleys for further research that we plan to investigate.

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[38]For instance, the definition of "front-loading" is now replaced by: A distribution $H_1(\cdot)$ is *more "front-loaded"* than a distribution $H_2(\cdot)$ if and only if:

$$\frac{1}{H_1(D)}\int_{\underline{D}}^{D} x h_1(x)dx < \frac{1}{H_2(D)}\int_{\underline{D}}^{D} x h_2(x)dx \text{ for all } D \in (\underline{D}, \bar{D}] \text{ (with equality at } \underline{D}).$$

This inequality simply means that the conditional expectations of the damages over the lower tail $[\underline{D}, D]$ is always greater with $H_2(\cdot)$ than with $H_1(\cdot)$. Then, one can easily show that the agency has more discretion with $H_1(\cdot)$ than with $H_2(\cdot)$.

[39]See Banks (1989) and Banks and Weingast (1992) on that issue.

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Appendix

• **Proofs of Propositions 1 and 3, Corollary 2:** Those proofs are immediate and thus omitted. ■

• **Proof of Lemma 1:** Fix a pair (D, D') such that $D > D'$. From (11), incentive compatibility constraints for D and D' respectively imply:

$$-D(1-e(D))-\psi(e(D))-(1-\alpha)R(e(D)) \geq -D(1-e(D'))-\psi(e(D'))-(1-\alpha)R(e(D'))$$

and

$$-D'(1-e(D'))-\psi(e(D'))-(1-\alpha)R(e(D')) \geq -D'(1-e(D))-\psi(e(D))-(1-\alpha)R(e(D))$$

Summing those two inequalities yields:

$$(D-D')(e(D)-e(D')) \geq 0.$$

Hence, $e(\cdot)$ is monotonically increasing and thus almost everywhere differentiable with (12) holding.

At any differentiability point, the first-order condition for (11) writes as (13). (12) is also the local second-order condition for (11). ■

• **Proof of Lemma 2:** Lemma 1 shows that $e(\cdot)$ has necessarily flat parts or is equal to $e^{SB}(\alpha_R, D)$. Observing that $e^{SB}(\alpha_R, D)$ is strictly increasing in D, our focus on continuous schemes implies that there exist necessarily two thresholds D_1 and D_2 such that (14) holds.
■

• **Proof of Proposition 4:** Using the fact that the optimal mechanism has a cap on the level of effort that can be implemented by the regulator, we can rewrite the maximand in $(\mathcal{P}_R^{SB})$ as

$$W_C(D^*) = S - \int_{\underline{D}}^{D^*} (D(1-e^{SB}(\alpha_R, D)) + \psi(e^{SB}(\alpha_R, D)) + (1-\alpha_C)R(e^{SB}(\alpha_R, D)))h(D)dD$$

$$-\int_{D^*}^{\bar{D}} (D(1-e^{SB}(\alpha_R, D^*)) + \psi(e^{SB}(\alpha_R, D^*)) + (1-\alpha_C)R(e^{SB}(\alpha_R, D^*)))h(D)dD.$$

Note that

$$\dot{W}_C(D^*) = \frac{\partial e^{SB}}{\partial D}(\alpha_R, D^*) \int_{D^*}^{\bar{D}} (D - \psi'(e^{SB}(\alpha_R, D^*)) - (1-\alpha_C)R'(e^{SB}(\alpha_R, D^*)))h(D)dD.$$

Note that $W_C(D^*)$ is quasi-concave since

$$\Phi(D^*) = \frac{\dot{W}_C(D^*)}{\frac{\partial e^{SB}}{\partial D}(\alpha_R, D^*)} = \int_{D^*}^{\bar{D}} (D - \psi'(e^{SB}(\alpha_R, D^*)) - (1-\alpha_C)R'(e^{SB}(\alpha_R, D^*)))h(D)dD$$

is decreasing in D^* with

$$\dot{\Phi}(D^*) = -(\alpha_R - \alpha_C)R'(e^{SB}(\alpha_R, D^*))h(D^*)$$

$$-\frac{\partial e^{SB}}{\partial D}(\alpha_R, D^*)(\psi''(e^{SB}(\alpha_R, D^*)) + (1-\alpha_C)R''(e^{SB}(\alpha_R, D^*))(1-H(D^*)) < 0.$$

Optimizing $(\mathcal{P}_R^{SB})$ with respect to D^* yields therefore the following necessary first-order condition for an interior solution $D^*(\alpha_R)$, $\dot{W}_C(D^*(\alpha_R)) = 0$ or

$$\int_{D^*(\alpha_R)}^{\bar{D}} (D - \psi'(e^{SB}(\alpha_R, D^*)) - (1-\alpha_C)R'(e^{SB}(\alpha_R, D^*(\alpha_R))))h(D)dD = 0 \qquad \text{(A.1)}$$

with a second-order condition being given at that point as

$$\ddot{W}_C(D^*(\alpha_R)) = -\frac{\partial e^{SB}}{\partial D}(\alpha_R, D^*(\alpha_R))(\alpha_R - \alpha_C)R'(e^{SB}(\alpha_R, D^*(\alpha_R))))h(D^*(\alpha_R))$$

$$-\left(\frac{\partial e^{SB}}{\partial D}(\alpha_R, D^*(\alpha_R))\right)^2 (\psi''(e^{SB}(\alpha_R, D^*(\alpha_R))) + (1-\alpha_C)R''(e^{SB}(\alpha_R, D^*(\alpha_R)))(1-H(D^*(\alpha_R))) \leq 0.$$
(A.2)

An interior $D^*(\alpha_R) \in (\underline{D}, \bar{D})$ solves (15) and is such that the second-order conditions above are satisfied.

Such interior solution arises necessarily when $\dot{W}_C(\underline{D}) > 0 = \dot{W}_C(\bar{D})$, i.e.,

$$\int_{\underline{D}}^{\bar{D}} (D - \psi'(e^{SB}(\alpha_R, \underline{D})) - (1-\alpha_C)R'(e^{SB}(\alpha_R, \underline{D})))h(D)dD > 0$$

or, taking into account the definition of e_C given in (10), when $e^{SB}(\alpha_R, \underline{D}) \leq e_C$.

Rigid rule: When instead $e^{SB}(\alpha_R, \underline{D}) > e_C$, $\dot{W}_C(\underline{D}) < 0$, and a rigid rule at e_C is optimal.

Partial discretion: Full discretion never arises since $D^* = \bar{D}$, although it solves (A.1) never satisfies the second-order condition (A.2).

Suboptimality of a floor: Suppose now that the agency adds a floor at $e^{SB}(\alpha_R, D^{**})$ with $D^{**} < D^*$

We can now rewrite Congress's objective as:

$$W_C(D^{**}, D^*) = S - \int_{D^{**}}^{D^*} (D(1-e^{SB}(\alpha_R, D)) + \psi(e^{SB}(\alpha_R, D)) + (1-\alpha_C)R(e^{SB}(\alpha_R, D)))h(D)dD$$

$$- \int_{D^*}^{\bar{D}} (D(1-e^{SB}(\alpha_R, D^*)) + \psi(e^{SB}(\alpha_R, D^*)) + (1-\alpha_C)R(e^{SB}(\alpha_R, D^*)))h(D)dD$$

$$- \int_{\underline{D}}^{D^{**}} (D(1-e^{SB}(\alpha_R, D^{**})) + \psi(e^{SB}(\alpha_R, D^{**})) + (1-\alpha_C)R(e^{SB}(\alpha_R, D^{**})))h(D)dD.$$

Observe then that:

$$\frac{\partial W_C}{\partial D^{**}}(D^{**}, D^*) = \frac{\partial e^{SB}}{\partial D}(\alpha_R, D^{**}) \int_{\underline{D}}^{D^{**}} (D - \psi'(e^{SB}(\alpha_R, D^{**})) - (1-\alpha_C)R'(e^{SB}(\alpha_R, D^{**})))h(D)dD$$

so that

$$\frac{\partial W_C}{\partial D^{**}}(\underline{D}, D^*) = 0$$

and

$$\frac{\partial^2 W_C}{\partial (D^{**})^2}(\underline{D}, D^*) = \frac{\partial e^{SB}}{\partial D}(\alpha_R, \underline{D})(\alpha_C - \alpha_R)R'(e^{SB}(\alpha_R, \underline{D}))h(\underline{D})$$

$$- \left(\frac{\partial e^{SB}}{\partial D}(\alpha_R, \underline{D})\right)^2 (\psi''(e^{SB}(\alpha_R, D^{**})) + (1-\alpha_C)R''(e^{SB}(\alpha_R, D^{**}))) \leq 0.$$

Hence, $D^{**} = 0$ is optimal. ■

• **Proof of Corollary 2:** Suppose that $H_1(\cdot)$ is more front-loaded than $H_2(\cdot)$, i.e., (17) holds. Denote by $D_i^*(\alpha_R)$ the optimal cap for distribution $H_i(\cdot)$. From (16), we have then:

$$\frac{1}{1-H_2(D)}\int_{D_1^*(\alpha_R)}^{\bar{D}} xh_2(x)dx > \psi'(e_R(D_1^*(\alpha_R))) + (1-\alpha_C)R'(e_R(D_1^*(\alpha_R))).$$

Using the fact that $W_C(\cdot)$ (when expectations are computed with $H_2(\cdot)$)) is quasi-concave, we have necessarily:

$$D_1^*(\alpha_R) < D_2^*(\alpha_R).$$

■

• **Proof of Corollary 3:** Because $exp(-\mu D^*)$ and $\frac{1}{\mu}$ are both decreasing, they both covary in the same direction which implies:

$$\frac{\Delta\alpha}{2-\alpha_R}D^*(\alpha_R) = \frac{E_k\left(\frac{exp(-\mu_k D^*(\alpha_R))}{\mu_k}\right)}{E_k\left(exp(-\mu_k D^*(\alpha_R))\right)} \geq E_k\left(\frac{1}{\mu_k}\right) = \frac{\Delta\alpha}{2-\alpha_R}E_k\left(D_k^*(\alpha_R)\right).$$

This yields (19). ■

• **Proof of Lemma 3:** The proof is similar to that of Lemma 1 and is thus omitted. ■

• **Proof of Proposition 6:**

Optimality condition: We can rewrite the maximand $W_C(e^*)$ in $(\mathcal{P}_R^{AI})$ as

$$W_C(e^*) = S - \int_{\bar{\Omega}} D(1-e^{SB}(\alpha,D)) + \psi(e^{SB}(\alpha,D)) + (1-\alpha_C)R(e^{SB}(\alpha,D)))dH(D)dG(\alpha)$$
$$- \int_{\Omega} D(1-e^*) + \psi(e^*) + (1-\alpha_C)R(e^*))dH(D)dG(\alpha)$$

where

$$\Omega = \{(\alpha,D) \in [\alpha_C,1]\times[\underline{D},\bar{D}] | D - \psi'(e^*) - (1-\alpha)R'(e^*) \geq 0\}$$

and

$$\bar{\Omega} = \{(\alpha,D) \in [\alpha_C,1]\times[\underline{D},\bar{D}] | D - \psi'(e^*) - (1-\alpha)R'(e^*) < 0\}.$$

Ω is the set of pairs (α, D) where the regulatory cap on effort binds.

Using that $\psi(\cdot)$ is quadratic, we get

$$e^{SB}(\alpha,D) = \frac{D}{\lambda(2-\alpha)}$$

and

$$\Omega = \left\{(\alpha,D) \in [\alpha_C,1]\times[\underline{D},\bar{D}] | 2-\alpha \leq \frac{D}{\lambda e^*}\right\} \text{ and } \bar{\Omega} = \left\{(\alpha,D) \in [\alpha_C,1]\times[\underline{D},\bar{D}] | 2-\alpha \leq \frac{D}{\lambda e^*}\right\}.$$

Observe then that:

$$W_C(e^*) = S + \int_{\bar{\Omega}} \left(-D + \frac{D^2}{\lambda(2-\alpha)} \left(1 - \frac{(2-\alpha_C)}{2(2-\alpha)} \right) \right) h(D)g(\alpha)dDd\alpha$$
$$+ \int_{\Omega} \left(-D(1-e^*) - \frac{\lambda(e^*)^2}{2}(2-\alpha_C) \right) h(D)g(\alpha)dDd\alpha.$$

We can rewrite this expression as:

$$W_C(e^*) = S + \int_{\underline{D}}^{\bar{D}} \left(-D + \int_{\alpha_C}^{\min\{2-\frac{D}{\lambda e^*};1\}} \frac{D^2}{\lambda(2-\alpha)} \left(1 - \frac{(2-\alpha_C)}{2(2-\alpha)} \right) g(\alpha)d\alpha \right) h(D)dD$$
$$+ \int_{\underline{D}}^{\bar{D}} \left(-D + \int_{2-\frac{D}{\lambda e^*}}^{1} \left(De^* - \frac{\lambda(e^*)^2}{2}(2-\alpha_C) \right) g(\alpha)d\alpha \right) h(D)dD.$$

Developing the first of those integrals (for the only relevant case where $\bar{D} > \lambda e^*$) yields:

$$W_C(e^*) = S + \int_{\underline{D}}^{\lambda e^*} \left(-D + \int_{\alpha_C}^{1} \frac{D^2}{\lambda(2-\alpha)} \left(1 - \frac{(2-\alpha_C)}{2(2-\alpha)} \right) g(\alpha)d\alpha \right) h(D)dD$$
$$+ \int_{\lambda e^*}^{\bar{D}} \left(-D + \int_{\alpha_C}^{2-\frac{D}{\lambda e^*}} \frac{D^2}{\lambda(2-\alpha)} \left(1 - \frac{(2-\alpha_C)}{2(2-\alpha)} \right) g(\alpha)d\alpha \right) h(D)dD$$
$$+ \int_{\lambda e^*}^{\bar{D}} \left(-D + \left(De^* - \frac{\lambda(e^*)^2}{2}(2-\alpha_C) \right) \left(1 - G\left(2 - \frac{D}{\lambda e^*} \right) \right) \right) h(D)dD.$$

We can now differentiate this expression with respect to e^* to obtain the optimal regulatory cap (assuming quasi-concavity of the objective).[40] This yields:

$$\dot{W}_C(e^*) = \int_{\lambda e^*}^{\bar{D}} (D - (2-\alpha_C)\lambda e^*) \left(1 - G\left(2 - \frac{D}{\lambda e^*} \right) \right) h(D)dD = 0 \qquad \text{(A.3)}$$

so that the optimal cap e^{AI} is given by condition (25) that is thus necessary and sufficient.

Approximation: Using the expression of $G_\epsilon(\cdot)$ given in the text, we obtain that $e^*(\epsilon)$ solves the following equation:

[40] Indeed, we get

$$\ddot{W}_C(e^*) = -(2-\alpha_C)\lambda \int_{\lambda e^*}^{\bar{D}} \left(1 - G\left(2 - \frac{D}{\lambda e^*} \right) \right) h(D)dD$$
$$- \int_{\lambda e^*}^{\bar{D}} (D - (2-\alpha_C)\lambda e^*) \frac{D}{\lambda(e^*)^2} g\left(2 - \frac{D}{\lambda e^*} \right) h(D)dD$$

so that quasi-concavity is ensured when the first term above always dominates.

$$f(e^*(\epsilon),\epsilon) = \int_{(2-\alpha_R-\epsilon)\lambda e^*(\epsilon)}^{(2-\alpha_R+\epsilon)\lambda e^*(\epsilon)} (D-(2-\alpha_C)\lambda e^*(\epsilon)) \left(1-\chi\left(\frac{2-\frac{D}{\lambda e^*(\epsilon)}-\alpha_R}{\epsilon}\right)\right) h(D)dD$$

$$+\int_{(2-\alpha_R+\epsilon)\lambda e^*(\epsilon)}^{\bar{D}} (D-(2-\alpha_C)\lambda e^*(\epsilon))h(D)dD = 0.$$

Note that

$$e^*(0) = e^{SB}(\alpha_R, D^*(\alpha_R)) = \frac{D^*(\alpha_R)}{\lambda(2-\alpha_R)} \quad \text{(A.4)}$$

where $D^*(\alpha_R)$ solves (16).

We look for a second-order approximation of $e^*(\epsilon)$ as:

$$e^*(\epsilon) = e^*(0) + \alpha\epsilon + \frac{\beta}{2}\epsilon^2.$$

Making second-order Taylor expansions of the condition $f(e^*(\epsilon),\epsilon) = 0$, we can find (α,β) as solutions to the following system:

$$f_e(e^*(0),0)\alpha + f_\epsilon(e^*(0),0) = 0 \text{ and } f_e(e^*(0),0)\beta + f_{\epsilon\epsilon}(e^*(0),0) + f_{ee}(e^*(0),0)\alpha^2 = 0. \quad \text{(A.5)}$$

First, observe that:

$$f_{e^*}(e^*,0) = -\lambda(2-\alpha_C)(1-H((2-\alpha_R)\lambda e^*)). \quad \text{(A.6)}$$

To compute the other derivatives, let us first consider:

$$g(e^*,\epsilon) = \int_{(2-\alpha_R-\epsilon)\lambda e^*}^{(2-\alpha_R+\epsilon)\lambda e^*} (D-(2-\alpha_C)\lambda e^*) \left(1-\chi\left(\frac{2-\frac{D}{\lambda e^*}-\alpha_R}{\epsilon}\right)\right) h(D)dD.$$

Introducing the change of variables $D = (2-\alpha_R+\epsilon x)\lambda e^*$ with $dD = \epsilon\lambda e^* dx$, we can rewrite

$$g(e^*,\epsilon) = (\lambda e^*)^2 \int_{-1}^{1} (-\Delta\alpha + \epsilon x)\epsilon\,(1-\chi(x))\, h((2-\alpha_R+\epsilon x)\lambda e^*)dx.$$

With this expression, it becomes easy to compute:

$$g_\epsilon(e^*,0) = (-\lambda e^*)^2\Delta\alpha h((2-\alpha_R)\lambda e^*) \int_{-1}^{1} (1-\chi(x))\, dx = -(\lambda e^*)^2\Delta\alpha h((2-\alpha_R)\lambda e^*)$$

since, by integrating by parts, we have $\int_{-1}^{1}(1-\chi(x))\,dx = 1$.

Also, we get:

$$g_{\epsilon\epsilon}(e^*,0) = (\lambda e^*)^2 \left(-\lambda e^* \Delta\alpha h'((2-\alpha_R)\lambda e^*) + 2h((2-\alpha_R)\lambda e^*)\right) \left(\int_{-1}^{1} x(1-\chi(x))dx\right) \tag{A.7}$$

where integrating by parts yields also $\int_{-1}^{1} x\,(1-\chi\,(x))\,dx = \frac{\sigma^2-1}{2}$.

Consider now

$$i(e^*,\epsilon) = \int_{(2-\alpha_R+\epsilon)\lambda e^*}^{\bar{D}} (D-(2-\alpha_C)\lambda e^*)h(D)dD.$$

Differentiating, we get

$$i_\epsilon(e^*,0) = (\lambda e^*)^2 \Delta\alpha h((2-\alpha_R)\lambda e^*) = -g_\epsilon(e^*,0).$$

Therefore, we get:

$$f_\epsilon(e^*,0) = g_\epsilon(e^*,0) + i_\epsilon(e^*,0) = 0$$

and thus

$$\alpha = 0. \tag{A.8}$$

Differentiating one more time

$$i_{\epsilon\epsilon}(e^*,0) = (\lambda e^*)^2 \left(\lambda e^* \Delta\alpha h'((2-\alpha_R)\lambda e^*) - h((2-\alpha_R)\lambda e^*)\right). \tag{A.9}$$

This leads to

$$f_{\epsilon\epsilon}(e^*,0) = g_{\epsilon\epsilon}(e^*,0) + i_{\epsilon\epsilon}(e^*,0)$$
$$= (\sigma^2-2)(\lambda e^*)^2 h((2-\alpha_R)\lambda e^*) - \left(\frac{\sigma^2-3}{2}\right)(\lambda e^*)^3 \Delta\alpha h'((2-\alpha_R)\lambda e^*).$$

Using (A.5), we get:

$$\beta = -\frac{f_{\epsilon\epsilon}(e^*(0),0)}{f_e(e^*(0),0)} =$$
$$-(2-\sigma^2)\frac{(\lambda e^*(0))^2 h((2-\alpha_R)\lambda e^*(0))}{\lambda(2-\alpha_C)(1-H((2-\alpha_R)\lambda e^*(0)))} + \left(\frac{3-\sigma^2}{2}\right)\frac{(\lambda e^*(0))^3 \Delta\alpha h'((2-\alpha_R)\lambda e^*(0))}{\lambda(2-\alpha_C)(1-H((2-\alpha_R)\lambda e^*(0)))}. \tag{A.10}$$

Taking into account (A.4), we finally obtain the following second-order approximation:

$$e^{AI}(\epsilon) = e^{AI}(0) -$$
$$\frac{\epsilon^2 (D^*(\alpha_R))^2}{2\lambda(2-\alpha_R)^2(2-\alpha_C)(1-H(D^*(\alpha_R)))}\left((2-\sigma^2)h(D^*(\alpha_R) - \frac{(3-\sigma^2)\Delta\alpha D^*(\alpha_R)}{2(2-\alpha_R)} h'(D^*(\alpha_R))\right) \tag{A.11}$$

Taking into account that for an exponential distribution $(1 - H(D) = exp(-\mu D)$ and $h(D) = \mu exp(-\mu D))$, $D^*(\alpha_R)$ is given by (18), and we obtain (26). ■

Proof of Proposition 7: Formally, the Executive looks for an optimal preference of the agency α_R which solves the following problem:

$$(\mathcal{P}_R^{\alpha_R}): \quad \max_{\alpha_R} S - E_D(D(1 - e(\alpha_R, D)) + \psi(e(\alpha_R)) + (1 - \alpha_E)R(e(\alpha_R, D)))$$

$$\text{where } e(\alpha_R, D) = \min\{e^{SB}(\alpha_R, D), e^{SB}(\alpha_R, D^*(\alpha_R))\}.$$

Denoting by $W_E(\alpha_R)$ the maximand above, it is straightforward to check that:

$$\dot{W}_E(\alpha_R) = (\alpha_E - \alpha_R) \int_{\underline{D}}^{D^*(\alpha_R)} R'(e^{SB}(\alpha_R, D)) \frac{\partial e^{SB}}{\partial \alpha_R}(\alpha_R, D) h(D) dD$$

$$+(\alpha_E - \alpha_C)(1 - H(D^*(\alpha_R)))R'(e^{SB}(\alpha_R, D^*(\alpha_R))) \frac{\partial e^{SB}}{\partial D}(\alpha_R, D^*(\alpha_R)) \dot{D}^*(\alpha_R).$$

When evaluating this derivative at $\alpha_R = \alpha_E$, i.e., at the point where the regulator's preferences are aligned with those of the Executive, we obtain:

$$\dot{W}_E(\alpha_E) = (\alpha_E - \alpha_C)(1 - H(D^*(\alpha_E)))R'(e^{SB}(\alpha_E, D^*(\alpha_E))) \frac{\partial e^{SB}}{\partial D}(\alpha_E, D^*(\alpha_E)) \dot{D}^*(\alpha_E).$$

Observe now that first, $\dot{D}^* < 0$ when $\alpha_E > \alpha_C$, i.e., the agency has less discretion when its preferences further diverge from those of Congress; second, $\frac{\partial e^{SB}}{\partial D} > 0$, i.e., a higher harm calls for higher levels of prevention. Hence, we have:

$$\dot{W}_E(\alpha_E) < 0.$$

Reducing α_R below α_E always improves the Executive's expected payoff.

Similarly, evaluating $\dot{W}_E(\alpha_R)$ at $\alpha_R = \alpha_C$ and taking into account that $D^*(\alpha_C) = \bar{D}$, we have

$$\dot{W}_E(\alpha_C) = (\alpha_E - \alpha_C) \int_{\underline{D}}^{\bar{D}} R'(e^{SB}(\alpha_R, D)) \frac{\partial e^{SB}}{\partial \alpha_R}(\alpha_R, D) h(D) dD > 0$$

since $\frac{\partial e^{SB}}{\partial \alpha_R} > 0$, i.e., a more "pro-firm" oriented regulator implements higher effort. Increasing α_R above α_C always improves the Executive's expected payoff. ■