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ABSTRACT

The Public Management of Environmental Risk: Separating *Ex Ante* and *Ex Post* Monitors*

When firms undertake activities that are environmentally risky, the divergence between social and private incentives to exert safety care requires public intervention. This control occurs both through *ex ante* regulation and *ex post* legal investigation. We delineate the respective scopes of those two kinds of monitoring when regulators and judges may not be benevolent. Separation between the *ex ante* and the *ex post* monitors of the firm helps to prevent capture. The likelihood of both *ex ante* and *ex post* inspections is higher under separation than under integration. This provides a rationale for the widespread institutional trend that has led to the separation of *ex ante* regulation from *ex post* prosecution. The robustness of this result is investigated in various extensions. Only when collusion is self-enforcing might it be possible that integration dominates separation.

JEL Classification: L51
Keywords: environmental risk, *ex ante* and *ex post* investigations, integration and separation, liability and regulation

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1 Introduction

The control of private actors involved in activities which put the environment at risk is a major challenge of our "risky society".[1] In a world where technological progress and innovation push always further the frontier of knowledge and render the assessment of risks more difficult, it becomes crucial to understand which institutional design improves risk regulation. Current responses to the threat of environmental risks have up to now mobilized the whole array of regulatory and legal interventions. Both regulation, whether it is by use of standards and ex ante monitoring, and legal investigation, by means of ex post monitoring and liability rules following an environmental hazard, have been indeed used to maintain safety care. An important issue, which remains by large unexplored, is to delineate the respective scopes of regulation and liability in a world plagued with informational constraints. To do so a crucial step is to take into account the incentives of regulators and judges, viewed respectively as ex ante and an ex post monitors of the firm's activities, when those public actors might be captured by the industry they are supposed to control.

This paper argues that a benefit from splitting the ex ante and the ex post monitoring of the firm arises because this institutional choice limits the scope for capture in a framework with moral hazard on safety care. Even though both the regulator and the judge may be corrupted, the separation of their tasks reduces the overall scope for capture. The agency cost of implementing a high standard of care generally decreases with separation and risk regulation is significantly improved.

Consider a risk-neutral firm protected by limited liability which undertakes some safety care effort that it finds costly to provide. The control of the firm's activities consists in, first, enforcing a high standard of care upon an ex ante regulatory inspection (possibly with incentive rewards and fines in case of non-compliance) and, second, imposing fines if an accident occurs and an ex post judiciary investigation is carried over. Both ex ante and ex post, different sorts of monitors (the regulator and the judge) obtain information on whether the firm has performed some care or not. This access to privileged information gives to those monitors discretion and creates the scope for their capture.

Had the ex ante and the ex post monitors been benevolent, monitoring would be used to improve the firm's incentives and reduce the agency cost of inducing safety care in a moral hazard framework. Quite intuitively, relying on ex post monitoring in case of an accident is of no help when the fines imposed as liability payments cannot exceed the regulatory punishments following a bad performance.

Things are different when monitors can be corrupted by the industry. Consider first

[1] Beck (1992) coined this expression.

the hypothetical case where both the ex ante and the ex post monitors are merged into a single entity: the case of integration. Postulating a technology for exchanging side-transfers which exhibits convex transaction costs, average transaction costs decrease as bribes can be smoothed in more states of nature. Since it intervenes both ex ante and ex post, a merged entity can significantly reduce transaction costs and reach quite efficient collusive deals.

Consider now the case of separation: two different monitors are used ex ante and ex post. At the time of striking a collusive deal, the firm and his ex ante monitor anticipates that an uncorrupted ex post monitor may intervene. This reduces the possibility for exchanging bribes over the different future contingencies and increases transaction costs.

Splitting ex ante and ex post monitoring between the regulator and the judge helps instead increasing these transaction costs. Roughly speaking, there exist diseconomies of scale in side-contracting that can be exploited by splitting tasks. We first show this result in the case where the probabilities of investigation are exogenously fixed. In a quite striking way, the fact that ex post intervention is undertaken by an independent judge not only makes it harder for the firm to capture its regulator but it ensures also that the stake for capturing the judge is null. Although a priori as non-benevolent as the regulator, the judge ends up not being captured in equilibrium and looks like being perfectly benevolent.

Since ex post monitoring of the firm's activity by the judge reduces the cost of regulatory capture, an ex post investigation is now called upon with a positive probability. By the same token, since ex ante regulatory capture is less of a concern, the likelihood of such monitoring increases. Our model generates thus a strong complementarity between ex ante and ex post monitoring.

This result on the benefits of separation is then challenged in various extensions. First, we show that risk-aversion on the firm's side generates such benefits of separation even when the collusion technology exhibits no transaction costs. Second, we argue that giving to judges the possibility to raise supplementary fines in case of an accident also exacerbates the benefits of separation.[2] Third, we investigate what happens when collusion is self-enforcing. We show there that integration may sometimes be good since raising the rewards that an ex post monitor may get for finding misconduct may destabilize ex ante collusive agreements: a strategy to fight collusion that is not available under separation.

The idea that splitting access to privileged information between several agencies reduces the agency costs of capture has previously been investigated by Laffont and Martimort (1998, 1999). Several important differences exist with the present setting. First, we focus here on moral hazard as the source of the rent that the firm wants to protect

[2]This can be viewed as a black-box for some legal procedures, like extended liability under CERCLA in the U.S. which aim at raising such fines.

by capturing its monitors whereas Laffont and Martimort (1998, 1999) dealt with adverse selection. Second, both the regulator and the judge have access to the same piece of information (even though it is at different points in time), the agent's level of safety care, whereas separated agencies get access to different pieces of information in Laffont and Martimort (1998, 1999). Another difference comes from the underlying justifications of the economies of scale that the side-contracting technology exhibits. In Laffont and Martimort (1998, 1999), building "Chinese Walls" between regulators creates asymmetric information in side-contracting. This undermines the efficiency of the side-deals that both regulators reach with the firm they are supposed to regulate. It becomes less efficient to achieve collusive deals with two agencies partially informed than with a single one. Here instead, the "technological gains" from separation come from the fact that a single regulator can better smooth bribes over the different states of nature if he also investigates the firm ex post.[3] Lastly, in Laffont and Martimort (1998, 1999), the monitoring technologies which give informative signals to the firm's monitors are exogenously given whereas, in this paper, we bear a particular attention to the impact of different institutional choices on the frequencies of both regulatory and judicial investigations.

There also exists a small literature on the corruption of law enforcers, mainly Becker and Stigler (1974), Mookherjee and P'ng (1995), Garoupa (1997) and Polinsky and Shavell (2001). These papers analyze the impact of corruption on the likelihood of investigation in various contexts but none of them draws, as we do, the consequences of corruption on institutional design and deals with the distinction between ex ante and ex post investigation. In these papers and contrary to ours, corruption is an equilibrium phenomenon. In our context, a version of the Collusion-Proofness Principle[4] holds so that institutions are always robust to the threat of capture but, of course, at a cost. The best institutional form minimizes this cost. This institutional perspective is also the focus of Boyer and Porrini (2001, 2004) who compare ex ante regulation and various liability rules. Contrary to us, they postulate a priori that the legal system is immune to capture. Also, they analyze separately the costs and benefits of the two systems whereas our model endogenizes their common use.

Our paper is also related to earlier contributions, like Witman (1977), Shavell (1984a, 1984b) and Kolstad, Ulen and Johnson (1990), which compare the use of ex ante regulation and ex post liability rules but impose exogenous constraints on instruments, on information or on both. These papers are silent on the institutional issues which are at the core of our analysis.

[3]This desire for bribes smoothing to reduce transaction costs of side-contracting comes from their assumed convexity. Faure-Grimaud and Martimort (2003) present another model building on that assumption. Section 5 of the present paper endogenizes this assumption.

[4]See Tirole (1986) for instance.

Also close to our concerns are Mookherjee and P'Ng (1992) and Hiriart, Martimort and Pouyet (2004) who also stress the difference between ex ante and ex post monitoring but address other sets of issues related to the fact that ex post, the size of a damage is better known than ex ante for the first paper and to the fact that judges are better able to unveil the liabilities of violators for the second. None of these papers endogenizes the separation between ex ante and ex post monitors.

Section 2 presents our basic model. Section 3 develops our benchmark, when ex ante and ex post monitors do not collude with the firm. Section 4 relaxes this assumption and studies the impact of collusion both when ex ante and ex post monitoring are either integrated or separated. Section 5 sketches a simple model in which the convexity of transaction costs of side-contracting is endogenized. We confirm there our main result on the superiority of separation. Section 6 introduces an asymmetry between the ex ante and the ex post monitors in the amount of fines they can charge and test the robustness of our findings.[5] Section 7 studies a different perspective on collusion, questioning the enforceability of side-contracts and how it may impact on institutional forms. Section 8 briefly concludes. All proofs are relegated to an Appendix.

2 The Model

In this section, we introduce our basic model which involves a firm running a technology which is environmentally risky. Moral hazard in the choice of safety care might a priori require both ex ante and ex post monitoring to control whether the firm abides to a standard of due care.

2.1 Incentives, Information and Control

Moral hazard. If an accident occurs, harmed third-parties suffer from a damage of social value $D > 0$. The probability that no accident occurs is increasing in the firm's effort in safety care e. This effort variable is, for simplicity, supposed to be binary, $e \in \{0, 1\}$, so that these probabilities are $\pi_1 > \pi_0$ (we denote $\Delta\pi = \pi_1 - \pi_0$ and assume that $\Delta\pi > \pi_0$). Exerting effort $e = 1$ entails a cost ψ for the firm whereas no cost is incurred otherwise.[6]

Moral hazard stems both the fact that the firm's effort is non-verifiable and from the

[5] In particular, we show that when the ex post monitor can implement additional fines if a misbehavior is detected the scope for separation increases.

[6] This normalization is without loss of generality. The cost of effort is non-monetary for simplicity although our modelling could easily be modified for monetary costs without changing the main lessons of the paper.

divergence between social and private incentives to exert care. Efficiency always calls for implementing the high level of effort provided that D is large enough. However, the firm wants to save on the cost of undertaking care.

Limits on liability. The firm owns some assets worth $w \geq 0$. These assets represent what can be observed and easily seized to compensate third-parties following an accident and/or when the firm's misbehavior has been detected.[7]

Regulatory contracts. In full generality, an incentive scheme consists of payments $\{t_a, t_n\}$ to the firm conditional on whether an accident has occurred or not.[8,9] Because the firm is cash-constrained, the following limited liability constraints must hold:

$$t \geq -w \qquad \forall t \in \{t_a, t_n\}. \tag{LL}$$

Although we focus on monetary rewards and punishments, a broader interpretation of these payments should be kept in mind. Indeed, bad environmental performances sometimes come also with damages to the fixed capital of the firm and to some stakeholders (like workers). Costs may also be indirect and include tightened future regulations, refusals by the government of authorizations and permits, and new taxes.[10] Rewards may also involve the firm's implicit gains in reputation vis-à-vis its customers, potential contracting partners, the government, its shareholders and the financial community.[11] This broader interpretation makes our modelling also useful in institutional contexts where regulation is limited and there may exist a ban on regulatory reward to the firm.

[7] We might expect that the true value of the firm's assets is greater than w. Indeed, firms running activities which involve a risk of substantial damage have been traditionally protected by such limits on their liability since the consequences of an accident are so staggering that no companies would fully insure them (see, e.g., the Price-Anderson Act in the U.S. for nuclear activities). Moreover, on top of institutional restrictions, environmentally risky ventures often enter into various activities ("flight-by-night" techniques, spin-offs of subsidiaries with little assets, etc...) which reduce the size of observable assets for the regulator and the judge.

[8] The firm is thus given a base remuneration t_a and might receive an additional reward $t_n - t_a$ following a good environmental performance. Although we do not impose any restriction on the transfers except the limited liability requirements, we will always obtain that $t_n - t_a > 0$ in the different configurations that we study later.

[9] There will be two stages of monitoring in our model: before and after an accident takes place. One could wonder if there is any gain in making the rewards and punishments contingent on the the outcome of the ex ante monitoring. As we will see below the possibility of imposing extra fines when a misbehavior is detected will correspondingly increase the space of transfers available. Also, there is no gain in offering different rewards and punishments following an unsuccessful ex ante investigation.

[10] As an example, in the U.S., D.O.E. grants licenses to nuclear waste management utilities for a 20-year period with a possibility of extension.

[11] On the discussion of the indirect costs and benefits of environmental risks, see for instance Lesourd and Schilizzi (2001).

Ex ante monitoring. The regulation of risky activities often uses on-site random inspections to gather hard evidences on whether the firm complies with standards. This investigation takes place ex ante, i.e., before the realization of the underlying risk.

At a cost $C_r(p)$, an ex ante monitor observes a signal σ_r on the firm's effort level with probability p. To focus on interior solutions, $C_r(\cdot)$ is strictly increasing and sufficiently convex with $C_r(0) = 0$ and satisfies the Inada conditions $C_r'(0) = 0$ and $C_r'(1) = +\infty$. σ_r may be either equal to the firm's effort or not uninformative: $\sigma_r \in \{e, \emptyset\}$ with respective probabilities $\varepsilon_r > 0$ and $1 - \varepsilon_r$. ε_r stands thus for the accuracy of the regulator's signal. The cost $C_r(.)$ stands for the resources devoted to ex ante monitoring.

When the ex ante monitor detects that the firm has not exerted any care, he can force compliance so that the firm adopts the standard of due care, $e = 1$. The enforcement of that standard is also accompanied by monetary fines to punish misconduct.[12] We denote by $\{F_a^r, F_n^r\}$ the fines if the firm has been caught shirking. Of course, the firm's limited liability puts an upper bound on those fines:

$$t_s - F_s^r \geq -w \qquad \forall\, s \in \{a, n\}. \tag{LP_r}$$

Ex post monitoring. In the event of an accident, an ex post monitor[13] is called for to inspect whether the firm has followed a standard of due care or not. Of course, that intervention is only relevant when the ex ante regulator did not himself intervene ex ante or has intervened but was unsuccessful in unveiling the firm's effort.[14]

An ex post monitor can, at a cost $C_j(q)$, observe a hard information signal $\sigma_j \in \{e, \emptyset\}$ with probability q. That signal allows to perfectly assess the firm's effort with probability $\varepsilon_j > 0$ and is not informative with probability $1 - \varepsilon_j$. Still to ensure interior solutions, $C_j(\cdot)$ is strictly increasing and sufficiently convex with $C_j(0) = 0$, and satisfies the Inada conditions $C_j'(0) = 0$, $C_j'(1) = +\infty$. If, in case of an accident, the ex post monitor figures out that the firm has not followed a high standard of care, the firm can be fined.[15] Of course, this fine is still limited by the value of the firm's assets:

$$t_a - F_a^j \geq -w. \tag{LP_j}$$

The investigation costs borne either ex ante or ex post may differ to capture differences

[12]This modelling of the ex ante regulatory intervention echoes that found in Shavell (1984a, 1984b)'s analysis of the optimal mix between regulation and liability. The difference relies on the fact that safety care becomes verifiable only when the regulator audits the firm and finds evidences that the firm has not exerted the desirable effort level.

[13]This can be any accident investigation commission intervening ex post.

[14]Otherwise, a high standard of safety care has already been set and ex post investigation is of no value.

[15]Note there is no point in enforcing another level of effort at this last stage of the game.

in the administrative costs of the two systems. Except in this respect and in the points in time at which they intervene, ex ante and ex post monitors are thus quite similar.

Timing. The sequence of events unfolds as follows:

- At date 0, an incentive scheme is offered to the firm and its monitors. It specifies transfers $\{t_a, t_n\}$; probabilities $\{p, q\}$ of ex ante and ex post investigation; fines $\{F_n^r, F_a^r\}$ and F_a^j when misbehavior is detected; and compensations for the monitors which depend on their reports on whatever signals they may get.
- At date 1, the firm exerts an effort $e \in \{0, 1\}$.
- At date 1^+, the ex ante monitor inspects the firm with probability p. This monitor learns signal σ_r about the firm's choice of safety care effort. If he detects a misconduct ($\sigma_r = e = 0$), he forces the firm to implement the high level of effort ($e = 1$) and imposes fines $\{F_n^r, F_a^r\}$.
- At date 2, an accident occurs with probability $\pi(e)$.
- At date 2^+, in the event of an accident and if the ex ante inspection has been unsuccessful, the ex post monitor investigates with probability q. If he detects a misconduct ($\sigma_j = e = 0$), he imposes a fine F_a^j.
- At date 3, transfers, fines and compensations are implemented.

Note that the judge intervenes only when the regulator has failed in enforcing the standard. The negligence rule applies thus: the firm is protected from legal investigation if there is hard evidence that it performed due care.

2.2 Preliminaries

Incentive compatibility. To induce the firm to exert an effort, the following incentive compatibility constraint must hold:

$$\begin{aligned} U \equiv \pi_1 t_n + (1-\pi_1)t_a - \psi \geq\ & p\varepsilon_r \left\{\pi_1 \left[t_n - F_n^r\right] + (1-\pi_1)\left[t_a - F_a^r\right] - \psi\right\} \\ & + (1-p\varepsilon_r)\left\{\pi_0 t_n + (1-\pi_0)q\varepsilon_j \left[t_a - F_a^j\right] + (1-\pi_0)(1-q\varepsilon_j)t_a\right\}. \quad (1) \end{aligned}$$

The l.h.s. of (1) is the firm's expected profit if it complies and exerts care. Upon a successful ex ante inspection, no misconduct is detected and no fine can be imposed. If the ex ante inspection has been unsuccessful and a damage occurs, the ex post monitor may get information on the firm's effort but cannot show any misconduct either, so that fines are also not imposed.

The r.h.s., although intuitive, is slightly more involved. With probability p, an ex ante inspection occurs and detects non-compliance with probability ε_r. In this scenario, ex ante fines are imposed by the regulator and the firm is forced to exert care. With probability $1 - p\varepsilon_r$, either no regulatory investigation takes place or that intervention is unsuccessful. In this case, an ex post inspection may be successful following an accident, detect violation and impose fines with probability $(1 - \pi_0)q\varepsilon_j$.

The Maximal Punishment Principle[16] can be used to simplify (1). The firm's incentive compatibility constraint is relaxed when the punishments imposed are as large as possible. Constraints (LP_r) and (LP_j) must thus bind. We can rewrite (1) as:

$$U \geq (1-p\varepsilon_r)\left\{\pi_0 t_n + (1-\pi_0)(1-q\varepsilon_j)t_a\right\} - \left\{p\varepsilon_r + (1-\pi_0)(1-p\varepsilon_r)q\varepsilon_j\right\} w - p\varepsilon_r\psi. \quad (IC)$$

Participation. When the firm exerts an effort, its participation constraint writes as:[17]

$$U \geq 0. \quad (IR)$$

Monitors compensations. To simplify the exposition, we directly consider that whenever a monitor does not reveal any information on the firm's effort, he gets his reservation wage normalized at zero.[18]

When a monitor reports evidences about the firm's choice of safety care, his compensation does not depend on the effort exerted by the firm. This can be justified if the signal $\sigma_i = e = 1$ $(i = r, j)$ is only partially verifiable and can be manipulated into a signal $\hat{\sigma}_i = e = 0$. Indeed, if the monitors' compensation could depend on the firm's effort, collusion could be fought at no cost by offering a wage to the monitor only when he reveals that the firm has shirked on safety care, an event which does not occur along the equilibrium path. However, when evidences on effort can be manipulated, this compensation can no longer depend on the firm's effort.[19]

Three wages are thus relevant and should be considered in the rest of the model: V_{ante} is the wage offered to an ex ante monitor when he reports the firm's effort after an ex ante investigation; $\tilde{V}_{\text{post}}$ corresponds to the compensation given to a successful ex post monitor if the ex ante investigation has been unsuccessful; and lastly, V_{post} is the wage offered to a successful ex post monitor if the ex ante investigation was not undertaken.

[16]See Becker (1968) and Baron and Besanko (1984).

[17]Without loss of generality, the firm's payoff if it refuses the regulatory contract is normalized to zero.

[18]Indeed, a usual feature is that preventing collusion requires paying monitors only when they reveal information that gives them discretion vis-à-vis the firm. See Tirole (1986) for instance.

[19]Note that the signal $\sigma_i = e = 0$ does not need to be manipulable in fact.

Participation constraints for the monitors write thus as:

$$V_{\text{ante}}, \tilde{V}_{\text{post}}, V_{\text{post}} \geq 0. \tag{IR_i}$$

Following Niskanen (1971) and Laffont and Tirole (1993), these compensations should also be given a broader interpretation. They can stand for the share of the agency budget or resources that can be diverted for private use. Alternatively, they can also be considered as proxies for career concerns. If this perspective is taken, the regulatory transfers could simply be the product of the probability of getting a promotion times the private benefit associated to that new job.[20]

We denote the expected wage left to monitors as:

$$V(p,q) = p\varepsilon_r V_{\text{ante}} + p(1-\varepsilon_r)(1-\pi_1)q\varepsilon_j \tilde{V}_{\text{post}} + (1-p)(1-\pi_1)q\varepsilon_j V_{\text{post}}.$$

We shall focus on two institutional settings. In the first one, called *integration*, the ex ante and ex post monitors form a single entity. In the second one, called *separation*, they behave non-cooperatively.

Social objective. Social welfare incorporates the well-being of harmed third-parties but also the cost of providing incentives (including not only the social cost of regulatory transfers but also the administrative costs of any enforcement):[21,22]

$$W = S - (1-\pi_1)D - [\pi_1 t_n + (1-\pi_1)t_a + V(p,q)] - C_r(p) - C_j(q),$$

where S is the social benefit associated to the firm's activity. We will suppose that S is large enough so that the shut-down of the firm is never a valuable option.

3 Benevolent Monitors

Let us suppose that the ex ante and ex post monitors are both benevolent. We first find the minimum agency cost necessary to implement care given the investigation probabilities. Second, we determine these optimal probabilities taking into account this agency cost.

[20] Note that, whatever the interpretation behind these compensations, they remain always socially costly. For instance, rewarding a monitor for a zealous behavior by moving him towards higher positions in the bureaucratic hierarchy may come at the opportunity costs of not rewarding somebody more talented for this alternative job.

[21] Since the firm exerts the high level of care at the optimum, fines do not enter social welfare.

[22] We could generalize easily this objective function to take into account some redistributional issues. For instance, Congress could be more or less aligned with the harmed third-parties depending on whether the risk is global or local (i.e., whether it affects or not a significant share of the electorate). Also, the regulatory and the legislative bureaucracies could receive different weights in the social welfare function. Our modelling choice is made for simplicity but our results would hold more generally as well.

For fixed probabilities of inspection p and q, the high level of care is implemented at a cost $\mathcal{C}^*(p,q)$ such that:

$$\mathcal{C}^*(p,q) = \min_{\{t_n, t_a\, V_{\text{ante}}, \tilde{V}_{\text{post}}, V_{\text{post}}\}} \{U + V(p,q) + C_r(p) + C_j(q)\}$$
$$\text{s.t. } (LL),\ (IC),\ (IR),\ (IR_i).$$

Since both monitors are benevolent and report truthfully, their wages are optimally set at zero.

We will be particularly interested in a regime where only the incentive compatibility constraint (IC) and the limited liability constraint in the event of an accident are binding. For this to be true, we need the following assumption.

Assumption 1 $1 - \pi_1 < (1 - p\varepsilon_r)(1 - q\varepsilon_j)(1 - \pi_0)$.

Our second assumption ensures that the firm cannot be made residual claimant for its choice of safety care so that it earns a positive rent at the optimum.

Assumption 2 $w < \frac{\pi_0(1-p\varepsilon_r)-\pi_1 p\varepsilon_r}{\Delta\pi+\pi_0 p\varepsilon_r}\psi$.

Under Assumption 2, the firm's assets are not large enough to make the firm residual claimant for the impact of its care decision. $\{t_n, t_a\}$ are determined by having both the limited liability constraint in the event of an accident and the incentive compatibility constraint binding:

$$t_a^* = -w \quad \text{and} \quad t_n^* = -w + \frac{(1-p\varepsilon_r)\psi}{\Delta\pi + \pi_0 p\varepsilon_r} \tag{2}$$

and the firm's liability rent is positive:

$$\mathcal{U}(p) = -w + \frac{\pi_0(1-p\varepsilon_r) - \pi_1 p\varepsilon_r}{\Delta\pi + \pi_0 p\varepsilon_r}\psi.$$

The firm's rent does not depend on the likelihood of an ex post monitoring. To understand this result, let us come back to the moral hazard incentive constraint (1). Consider that the firm has not complied, nothing has been learned about the firm's effort following the ex ante investigation (with probability $1-p\varepsilon_r$) and an accident occurs (with probability $1-\pi_0$). Only then may the ex post monitor intervene. Whether an ex post investigation is launched or not, the firm's ex post payoff will be the same. Intuitively, moral hazard combined with limited liability forces t_a^* to extract all the firm's wealth. This prevents the ex post monitor from implementing any extra penalty when he intervenes himself. Ex post monitoring does not play a priori any role.

The optimal probabilities of investigation $\{p^*, q^*\}$ are given by:

$$\{p^*, q^*\} = \arg\min_{\{p,q\}} \left\{ \mathcal{C}^*(p,q) = \mathcal{U}(p) + C_r(p) + C_j(q) \right\}.$$

Proposition 1 *Assume that Assumptions 1 and 2 both hold. Then, there is no ex post investigation, $q^* = 0$ and only the ex ante investigation takes place with a strictly positive probability $p^* > 0$ such that*[23]

$$C_r'(p^*) = -\frac{\partial \mathcal{U}}{\partial p}(p^*) = \frac{\varepsilon_r \pi_1^2 \psi}{(\Delta\pi + \pi_0 p^* \varepsilon_r)^2}. \tag{3}$$

Increasing the probability of ex ante monitoring relaxes the firm's incentive constraint (IC). It is indeed less useful to raise the transfer t_n^* to provide incentives to the firm. Ex ante monitoring is a substitute for explicit monetary rewards following a good environmental performance.

Since ex post monitoring takes place only following an accident and the incentive transfer t_a^* in this state saturates already the firm's limited liability constraint, there is no benefit from using it. There is no benefit of using judges when regulators are benevolent.

Remark: It is worth coming back to Assumptions 1 and 2 which ensure that the firm enjoys a strictly positive rent. Suppose instead that the equilibrium investigation probabilities defined in Proposition 1 violate Assumption 1. Then, consider a (cost-reducing) decrease of the ex ante investigation probability at $\tilde{p}$ such that $1 - \pi_1 = (1 - \tilde{p}\varepsilon_r)(1 - \pi_0)$. It is thus immediate to check that there exists a set of incentive transfers such that the firm earns no rent while the incentive and limited liability constraints are also met. As we argued previously, incentive transfers and monitoring are somewhat substitutes. A very efficient ex ante monitoring technology annihilates the firm's incentives to undertake the low safety care effort. If Assumption 2 does not hold at equilibrium, then the conflict between the provision of incentives and the extraction of the firm's rent disappears. In both cases, since the firm's profit is null, collusion stakes would vanish if capture were an issue. In order to streamline the analysis, we shall assume in the sequel that both Assumptions 1 and 2 are always met.

[23] $\mathcal{U}(.)$ is convex in p so that the first-order condition is necessary and sufficient.

4 The Threat of Capture

Capture. A firm might bribe[24] its monitors in exchange for lenient stances on their sides. Indeed, the discretion of either monitor comes from the possibility he has to hide a misconduct, i.e., to report he has observed $\sigma_r = \emptyset$ (respectively, $\sigma_j = \emptyset$) when instead $\sigma_r = e = 0$ (respectively, $\sigma_j = e = 0$). By doing so, the monitor prevents the firm from paying fines if he receives a share of the corresponding benefit.

The firm has all bargaining power in proposing bribes to the monitor(s). A monitor accepts such a collusive side-contract if he gets more by doing so than by being honest.

If a bribe $\tau \geq 0$ is transferred from the firm to his monitor, the latter only enjoys a private benefit $k(\tau)$ where $0 \leq k(\tau) \leq \tau$ for any bribe, $k(\cdot)$ is increasing concave with $k'''(.) \geq 0$ (for technical reasons). That private benefits are less than transferred bribes captures the existing transaction costs of side-contracting. We assume that these transaction costs are convex.[25] Colluding partners are thus willing to design side-deals which minimize the dead-weight loss of side-contracting.

Even though collusion is illegal, a side-contract is supposed to be enforceable as most of the literature on collusion following Tirole (1986, 1992) does.[26] This assumption provides thus an upper bound on the efficiency of any side-deal and on its cost for society.

This commitment assumption bites at two levels in our framework, namely within and across periods. First, the promise of any bribe must be fulfilled once this monitor has taken a lenient stance vis-à-vis the firm. Second, when collusion takes place with the ex ante monitor, a side-contract must involve transfers in different states of nature which may arise later on and players must be able to commit to the corresponding collusive strategies. We will first focus on such strong norm of collusion and study later on a weaker form with imperfect commitment.

Collusion-Proofness. The collusive strategy that a firm may undertake with its monitors should be viewed as another dimension of the moral hazard problem. Since side-contracts are non-verifiable and thus cannot be directly banned, the optimal incentive scheme must not only induce the firm to exert care but also to offer the null collusive side-contract.

[24]Bribes may take the form of promises of future jobs for current regulators, direct monetary bribes or campaign contributions targeted towards lawmakers and key elected officials who have influence at the various stages of the firm's monitoring. As an example, Envirocare, which is the only private dump that handles the U.S. Government's nuclear waste, has acknowledged paying \$600,000 to the state regulator responsible for the dump's license and safety; it is also a major contributor to both sides of local politics.

[25]This is also a standard assumption in the public choice and regulation literatures (see Congleton (1984) and Faure-Grimaud and Martimort (2003)).

[26]One can think of reputation-like phenomena stemming from a repeated relationship between the firm and the regulator/judge that may make these illegal side-contracts enforceable. "Word-of-honor" between colluding partners may also help achieve this commitment.

Restricting attention to collusion-proof regulatory policies turns thus to be optimal in our context when D is large. It is akin to ensuring that the firm does not want to simultaneously deviate by both exerting a low level of care and then colluding with monitors to hide this choice.

4.1 Integration

Let us first suppose that both monitors are merged into a single entity. His discretion comes from the possibility to coordinate his reports at the various stages of the monitoring process. When collusion occurs ex ante, the enforceability of the side-contract provides the colluding partners with the ability to commit and to enforce collusion ex post too. Indeed, if the integrated monitor colludes with the firm at the ex ante stage, he hides to the public evidences of misconduct. Therefore, if the integrated monitor is also asked to intervene ex post following an accident, the ex ante side-contract stipulates that the firm's misconduct behavior won't be publicized at this stage also.

Ex Ante Collusion. When an ex ante investigation is successful, the merged monitor may hide information on the low effort performed by the firm and let the firm enjoy the corresponding benefits. The merged entity commits also not to reveal information if an ex post investigation is called for, even though it would generate hard evidences on the firm's misconduct. In exchange, the firms offers bribes $\{\tau_n, \tau_{a1}, \tau_{a2}\}$ when an accident does not occur (with probability π_0), an accident occurs but ex post investigation is not successful (with probability $(1-\pi_0)(1-q\varepsilon_j)$), or finally when an accident occurs and ex post investigation is successful (with probability $(1-\pi_0)q\varepsilon_j$).

The optimal side-contract solves thus:

$$\{\tau_n^I, \tau_{a1}^I, \tau_{a2}^I\} = \arg \max_{\{\tau_n,\tau_{a1},\tau_{a2}\}} \{\pi_0(t_n - \tau_n) + (1-\pi_0)(1-q\varepsilon_j)(t_a - \tau_{a1}) + (1-\pi_0)q\varepsilon_j(t_a - \tau_{a2})\},$$
$$\text{s.t. } (LT^I): \pi_0 k(\tau_n) + (1-\pi_0)(1-q\varepsilon_j)k(\tau_{a1}) + (1-\pi_0)q\varepsilon_j k(\tau_{a2}) \geq V^I_{\text{ante}},$$

where V^I_{ante} is the monitor's wage if he discovers and reports the firm's choice of effort. Constraint (LT^I) stems from the fact that the monitor's gain from accepting the side-contract must be larger than his wage if he reports a misconduct.[27]

Smoothing bribes reduces transaction costs of side-contracting. This requires adopting a flat bribe. Given that the firm has all bargaining power in side-contracting, this bribe

[27]Notice that the integrated monitor could hide the informative signal he has learned ex ante and wait until an ex post investigation is called for if the expected benefit of doing so exceeds the gain from an immediate deviation. If $V^I_{\text{ante}} \leq (1-\pi_0)q\varepsilon_j \tilde{V}^I_{\text{post}}$, the integrated monitor delays the revelation of the firm's misconduct. As we will see later on in this section, the optimal collusion-proof wages without taking into account this possibility for delaying information is such that $V^I_{\text{ante}} > 0 = (1-\pi_0)q\varepsilon_j \tilde{V}^I_{\text{post}}$, making delay unattractive. Note that delay is a priori also a possibility on the equilibrium path, i.e., when the firm exerts an effort. The corresponding constraint ($V^I_{\text{ante}} \geq (1-\pi_1)q\varepsilon_j \tilde{V}^I_{\text{post}}$) holds a fortiori since $\pi_1 > \pi_0$.

makes the merged entity just indifferent between colluding or not:

$$\tau_n^I = \tau_{a1}^I = \tau_{a2}^I \equiv \tau_{\text{ante}}^I = k^{-1}\left(V_{\text{ante}}^I\right).$$

The firm's gain from ex ante collusion is thus $\pi_0 t_n + (1-\pi_0)t_a - k^{-1}(V_{\text{ante}}^I)$ whereas if collusion does not take place ex ante, the firm gets $-w-\psi$. Therefore, a policy is *ex ante collusion-proof* when the merged entity receives a wage V_{ante}^I satisfying the following ex ante collusion-proofness constraint:

$$V_{\text{ante}}^I \geq k\left(\pi_0 t_n + (1-\pi_0)t_a + w + \psi\right). \qquad (CP_{\text{ante}}^I)$$

Ex Post Collusion. If an ex ante investigation is not successful or has not been launched at all, the merged entity might still intervene ex post. Collusion occurs if the firm has not exerted any effort, the monitor intervenes ex post (with probability q) and obtains a signal σ_j which is informative on the firm's effort (with probability ε_j). An optimal ex post side-contract solves now:

$$\begin{aligned} \tau_{a3}^I = &\arg\max_{\{\tau_{a3}\}} \{t_a - \tau_{a3}\} \\ &\text{s.t. } k(\tau_{a3}) \geq V_{\text{post}}^I, \tilde{V}_{\text{post}}^I, \end{aligned}$$

where different ex post wages $\tilde{V}_{\text{post}}^I$, V_{post}^I may be offered depending on whether an ex ante investigation has been launched but was unsuccessful or has not been launched at all.

The optimal bribe in each case is of course $\tau_{a3}^I \equiv \tau_{\text{post}}^I = k^{-1}(V_{\text{post}}^I)$ or $\tilde{\tau}_{a3}^I \equiv \tilde{\tau}_{\text{post}}^I = k^{-1}(\tilde{V}_{\text{post}}^I)$. Ex post collusion does not benefit the firm when the following *ex post collusion-proofness constraints* hold:

$$V_{\text{post}}^I, \tilde{V}_{\text{post}}^I \geq k(t_a + w). \qquad (CP_{\text{post}}^I)$$

Collusion. Let us now describe the firm's incentive constraint when collusion is an issue. The incentive scheme must be such that not exerting any effort and enjoying the gains from colluding either ex ante or ex post is not a profitable option. Preventing collusive deviations leads us to rewrite the following *generalized incentive constraint* which aggregates all possible deviations available to the firm:

$$\begin{aligned} U \geq\ & p\varepsilon_r \max\left\{-w-\psi; \pi_0 t_n + (1-\pi_0)t_a - k^{-1}(V_{\text{ante}}^I)\right\} \\ &+ (1-p\varepsilon_r)\left(\pi_0 t_n + (1-\pi_0)(1-q\varepsilon_j)t_a\right) + (1-p)(1-\pi_0)q\varepsilon_j \max\left\{-w; t_a - k^{-1}(V_{\text{post}}^I)\right\} \\ &+ p(1-\varepsilon_r)(1-\pi_0)q\varepsilon_j \max\left\{-w; t_a - k^{-1}(\tilde{V}_{\text{post}}^I)\right\}. \quad (GIC^I) \end{aligned}$$

Response to the Threat of Capture. The optimal incentive scheme solves:

$$\begin{aligned} \mathcal{C}^I(p,q) = &\min_{\{t_n, t_a, V_{\text{ante}}^I, \tilde{V}_{\text{post}}^I, V_{\text{post}}^I\}} \left\{U + V^I(p,q) + C_r(p) + C_j(q)\right\}, \\ &\text{s.t. } (LL),\ (GIC^I),\ (CP_{\text{ante}}^I),\ (CP_{\text{post}}^I),\ (IR),\ (IR_i) \end{aligned}$$

where

$$V^I(p,q) = p\varepsilon_r V^I_{\text{ante}} + p(1-\varepsilon_r)(1-\pi_1)q\varepsilon_j \tilde{V}^I_{\text{post}} + (1-p)(1-\pi_1)q\varepsilon_j V^I_{\text{post}}$$

is the expected wage of the merged entity.

Since giving up some rents for monitoring is socially costly, (CP^I_{ante}) and (CP^I_{post}) bind at the optimum. The ex ante and ex post wages of the merged entity are thus given by $V^I_{\text{ante}} = k(\pi_0 t_n + (1-\pi_0)t_a + w + \psi)$, and $\tilde{V}^I_{\text{post}} = V^I_{\text{post}} = k(t_a + w)$.

With these wages, (GIC^I) coincides with (IC). The optimal transfers $\{t^I_a, t^I_n\}$ are thus still given by (2), leaving the firm with the same rent $\mathcal{U}(p)$. We finally obtain:

$$V^I_{\text{ante}} = k\left(\frac{\pi_1\psi}{\Delta\pi + \pi_0 p\varepsilon_r}\right) \quad \text{and} \quad V^I_{\text{post}} = \tilde{V}^I_{\text{post}} = 0. \tag{4}$$

It is worth stressing that the merged entity never receives any wage for an ex post investigation. Again this is a consequence of the fact that the optimal transfer t^I_a just hits the firm's resources and leaves no scope for bribery in case of ex post investigation.

For future references, note that the "potential" bribe in an ex ante collusion is $\tau^I_{\text{ante}} = \frac{\pi_1\psi}{\Delta\pi+\pi_0 p\varepsilon_r}$.

Investigation Probabilities. The optimal investigation probabilities are now given by:

$$\{p^I, q^I\} = \arg\min_{\{p,q\}} \left\{\mathcal{C}^I(p,q) = \mathcal{C}^*(p,q) + p\varepsilon_r k\left(\frac{\pi_1\psi}{\Delta\pi + \pi_0 p\varepsilon_r}\right)\right\}.$$

Proposition 2 *Under integration and the threat of capture, the probability of an ex ante investigation is positive whereas there is still no ex post investigation: $p^I \geq 0$ and $q^I = 0$. The threat of capture calls also for a less frequent ex ante investigation: $p^I \leq p^*$.*

The probability of ex post monitoring still does not enter neither on the definition of the transfers $\{t^I_n, t^I_a\}$ nor on the wage to the integrated entity V^I. Hence, there is no reason to use ex post monitoring just as when monitors are benevolent.

Coming now to the probability of ex ante investigation, two opposite effects are at play simultaneously. For a fixed collusive stake, reducing this probability helps saving on the expected wage needed to ensure ex ante collusion-proofness. However, increasing this probability helps also, as before, to relax the incentive constraint (IC) and reduce the costly incentive reward t^I_n. The stake of collusion between the merged entity and the firm is thereby reduced and the collusion-proofness constraint (CP^I_{ante}) is relaxed. The second of these two effects always dominates. The probability of ex ante investigation is reduced compared with the benchmark situation.

4.2 Separation

Let us now consider the case where each round of investigation is run by a different entity. When colluding with the firm, the ex ante monitor anticipates that the ex post one will not collude because he expects him to abide to a collusion-proof policy. Similarly, when the ex post monitor is called upon, he expects that the ex ante one was not successful in his own investigation rather than corrupted.

Ex Ante Collusion. A side-contract for the ex ante monitor stipulates now bribes $\{\tau_n, \tau_{a1}\}$ both when an accident does not occur and when an accident does occur but no ex post investigation takes place. In case an ex post investigation takes place, the ex ante monitor can get no bribe from the firm when the (uncorrupted in equilibrium) ex post monitor publicly reveals a misconduct. The firm has no other issue than paying the maximal fine in that case so that nothing is left for bribing the ex ante monitor.

The optimal side-contract offered to the ex ante monitor when he observes $\sigma_r = 0$ and pretends that $\sigma_r = \emptyset$ must now solve:

$$\{\tau_n^S, \tau_{a1}^S\} = \arg\max_{\{\tau_n, \tau_{a1}\}} \{\pi_0(t_n - \tau_n) + (1-\pi_0)(1-q\varepsilon_j)(t_a - \tau_{a1}) - (1-\pi_0)q\varepsilon_j w\},$$
$$\text{s.t. } (LT^S) : \pi_0 k(\tau_n) + (1-\pi_0)(1-q\varepsilon_j)k(\tau_{a1}) \geq V_{\text{ante}}^S.$$

Again the dead-weight loss of side-contracting is minimized with a flat bribe:

$$\tau_n^S = \tau_{a1}^S \equiv \tau_{\text{ante}}^S = k^{-1}\left(\frac{V_{\text{ante}}^S}{\pi_0 + (1-\pi_0)(1-q\varepsilon_j)}\right).$$

The ex ante collusion-proofness constraint is now:

$$V_{\text{ante}}^S \geq (\pi_0 + (1-\pi_0)(1-q\varepsilon_j))k\left(\frac{\pi_0 t_n + (1-\pi_0)(1-q\varepsilon_j)t_a + [1-(1-\pi_0)q\varepsilon_j]w + \psi}{\pi_0 + (1-\pi_0)(1-q\varepsilon_j)}\right). \qquad (CP_{\text{ante}}^S)$$

Clearly, separation reduces the possibilities for smoothing bribes.

Ex Post Collusion. There is still no reason to offer different wages $\tilde{V}_{\text{post}}^S$ and V_{post}^S since whether the ex ante investigation took place (being unsuccessful) or not, the ex post collusion-proofness contraints are the same.

The corresponding optimal bribe is still $\tau_{\text{post}}^S = k^{-1}\left(V_{\text{post}}^S\right)$ and the collusion-proofness constraints for the ex post monitor write as under integration:

$$V_{\text{post}}^S \geq k(t_a + w). \qquad (CP_{\text{post}}^S)$$

Proceeding as before, the firm's generalized incentive constraint under separation still boils down to the standard incentive constraint.

Response to the Threat of Capture. To prevent capture under separation, the overall cost borne is now given by

$$V^S(p,q) = p\varepsilon_r V^S_{\text{ante}} + (1-p\varepsilon_r)(1-\pi_1)q\varepsilon_j V^S_{\text{post}}.$$

Characterizing the optimal collusion-proof transfers and wages is straightforward; $\{t^S_n, t^S_a\}$ are again given by (2). For fixed investigation probabilities, the wages of the ex ante and the ex post monitors are given by:

$$\begin{aligned} V^S_{\text{ante}} &= [\pi_0 + (1-\pi_0)(1-q\varepsilon_j)]k\left(\frac{\pi_1\psi}{(\Delta\pi + \pi_0 p\varepsilon_r)[\pi_0 + (1-\pi_0)(1-q\varepsilon_j)]}\right), \\ V^S_{\text{post}} &= 0. \end{aligned}$$

Summarizing, whether a merged entity is used or not has no impact on the optimal transfers which remain unchanged. Ex post intervention also is not rewarded. Even though the possibility of an ex post capture is taken into account, its stake is zero at the optimum.

Welfare Comparison. We can now compare how both institutional arrangements perform under the threat of collusion.

Note that, for a fixed pair (p,q) of audit probabilities, we have:

$$\begin{aligned} \Delta V \equiv V^I(p,q) - V^S(p,q) &= p\varepsilon_r(V^I_{\text{ante}} - V^S_{\text{ante}}), \\ &= p\varepsilon_r\left\{k\left(\tau^I_{\text{ante}}\right) - [\pi_0 + (1-\pi_0)(1-q\varepsilon_j)]k\left(\frac{\tau^I_{\text{ante}}}{\pi_0 + (1-\pi_0)(1-q\varepsilon_j)}\right)\right\}. \end{aligned}$$

Because $\pi_0 + (1-\pi_0)(1-q\varepsilon_j) \leq 1$, and $k(\cdot)$ is concave, we immediately get:

Proposition 3 *Under the threat of capture, separation improves welfare: $\Delta V > 0$.*

Since the ex ante monitor no longer intervenes ex post, bribes can no longer be smoothed. Transaction costs of side-contracting are not reduced as well as under integration. Even though it does not cost anything to ensure that the ex post monitor is not captured, the simple fact that the ex ante monitor is unable to collude ex post increases transaction costs and makes ex ante collusion less efficient.

Of course, if transaction costs of side-contracting were linear, non-benevolent monitors would not care about smoothing bribes and separation would be equivalent to integration.

Let us indeed compare the expected bribe that the firm provides to the ex ante monitor under separation and integration. Simple manipulations show that:

$$\tau^I_{\text{ante}} = [\pi_0 + (1-\pi_0)(1-q\varepsilon_j)]\tau^S_{\text{ante}} + q\varepsilon_j(1-\pi_0)(t^I_a + w) = [\pi_0 + (1-\pi_0)(1-q\varepsilon_j)]\tau^S_{\text{ante}}. \quad (5)$$

Hence, on average, the ex ante monitor under separation earns the same expected bribe than the ex ante monitor under integration. Indeed, as regards the firm's gain from ex ante collusion, separation and integration differ only in the case of a successful ex post investigation. Under separation, the firm loses w in that state, since it is caught shirking by the uncorrupted ex post monitor. Under integration, the merged monitor is committed to collude ex post and the firm's gain in that contingency is t^I_a. When the firm's limited liability binds, the expected gain from collusion is thus identical under integration and separation. Hence, the expected bribe to the ex ante monitor is the same across institutional modes.

However, bribes have more variance under separation. The convexity of the transaction costs of side-contracting ensures then that separation increases average transaction costs and improves welfare.

Investigation Probabilities. Let us turn to the optimal probabilities of investigation under separation. These probabilities are given by:

$$\{p^S, q^S\} = \arg\min_{\{p,q\}}\{\mathcal{C}^S(p,q) = \mathcal{C}^*(p,q) + p\varepsilon_r[\pi_0 + (1-\pi_0)(1-q\varepsilon_j)]k\left(\frac{\pi_1\psi}{(\Delta\pi + \pi_0 p\varepsilon_r)[\pi_0 + (1-\pi_0)(1-q\varepsilon_j)]}\right)\}.$$

Proposition 4 *Under the threat of capture, there is always more investigation (both ex ante and ex post) under separation than under integration: $p^S \geq p^I$ and $q^S \geq q^I = 0$.*

A recurrent question that emerges in the debate about whether to use regulators or judges concerns their substitutability or complementarity. Our model sheds some light on this issue. Indeed, it becomes more valuable to use ex ante investigation under separation because the threat of collusion is less socially costly. On the other hand, ex post intervention may now be *strictly* valuable. By raising at the margin the probability of bringing the judge in, one strictly increases the transaction costs of side-contracting, thereby making it harder for the ex ante regulator to collude with the firm.

5 Endogenous Transaction Costs

We now briefly sketch a less tractable model which yields the same insights as before without introducing what can be viewed as a somewhat ad hoc assumption on the side-contracting technology, namely the convexity of the transaction costs. We now assume that the firm is strictly risk-averse with a Bernoulli utility function defined over monetary gains. Bribes are transferred without friction from the firm to the monitors, i.e., $k(\tau) = \tau$.

Proposition 5 *Assume no friction in side-contracting but the firm is strictly risk-averse. Under the threat of capture, separation always strictly dominates integration.*

This result shows the strength and generality of Proposition 3. Even when side-transfers can be perfectly transferred, the slightest degree of risk aversion for the firm justifies separation.

The intuition is dual to that underlying Proposition 3. The risk-averse firm faces now a corruptible risk-neutral ex ante monitor. Risk aversion generates a demand for insurance over the future contingencies and the firm offers bribes which smooth its net monetary gains. Separation constrains these insurance possibilities and reduces the efficiency of the ex ante collusive side-agreement.

6 Optimal Penalties and Ineligibility for Immunity

Maximum Punishment Principle and Collusion-Proofness. So far, we have assumed that the penalty when an investigation reveals that the firm has chosen the low level of safety care was set at the highest value consistent with the firm's limited liability constraint (i.e., $t_n - F_n^r = t_a - F_a^r = t_a - F_a^j = -w$). However, the threat of collusion might affect the logic underlying the Maximum Punishment Principle. Indeed, consider a marginal decrease in, say, one of the ex ante penalties. Since the firm is less severely punished when caught shirking on safety care, it must receive a higher reward to be incentivized: t_n and the firm's expected rent both increase. This affects the collusive side-contract in two conflicting ways. First, the firm's gain being larger, it is willing to pay a greater bribe to the monitor. Second, the punishment being smaller, the firm is less eager to collude since it suffers less from the monitor's truthful report. As a result of these two conflicting forces, the impact of lowering the punishment on the collusive stake is ambiguous.

Nonetheless, as stated in the next proposition, the (socially costly) effect of smaller punishments on the firm's rent always offsets the (socially beneficial) impact on the tension between the collusive partners.

Proposition 6 *Under the threat of capture, the penalties associated to the different investigations are optimally set at the highest possible value whatever the institutional form.*

From a theoretical viewpoint, the previous proposition justifies our focus on maximal penalties. However, this result has an interesting practical content too.

Ineligibility for Immunity. It is often argued that one should not indemnify parties in case a negligent behavior has been detected. The firm's limits on its liability should be removed (via civil penalties for instance) if it can be ascertained that the firm has not complied with applicable regulations. Such a concern can be translated into two different possibilities in our framework.

First, in the event of an accident, if the ex post monitor gathers evidence that the firm has adopted a negligent behavior towards safety (i.e., $\sigma_j = e = 0$), then indemnification is removed and an additional penalty $\Delta_{\text{post}} \in [0, \Delta_{\text{post}}^{\max}]$ can be imposed on the firm.

Second, if the ex ante monitor discovers that the firm did not comply with applicable standards (i.e., $\sigma_r = e = 0$), then an additional penalty $\Delta_{\text{ante}} \in [0, \Delta_{\text{ante}}^{\max}]$ can be imposed. However, in the event of an accident, indemnification still limits the firm's liability.

Let us take as given the possibility of ineligibility for immunity if some misconduct has been detected either at the ex ante or at the ex post stage. How does that possibility affect our analysis?

Proposition 7 *Assume that, in the event of a successful ex ante (respectively, ex post) audit, the firm is no longer eligible for immunity and must pay a supplementary fine Δ_{ante} (respectively, Δ_{post}) if a negligent behavior has been detected:*

- *Civil Penalties Settlement: The supplementary fines must always be set at the highest possible value (i.e., $\Delta_{ante} = \Delta_{ante}^{max}$ and $\Delta_{post} = \Delta_{post}^{max}$).*
- *Ex Post Investigation: Even under integration, the equilibrium probability of an ex post investigation may be strictly positive; the ex post collusive stake is strictly positive when $\Delta_{post} > 0$.*
- *Increase in the Scope for Separation: Separation strictly dominates integration even with linear transaction costs and no desire for bribe smoothing.*

As concerns the determination of the optimal supplementary fines, the intuition is similar to the one underlying Proposition 6. Reducing that punishment below the highest possible value amounts to reducing the collusive stakes and to increase the firm's expected rent. Overall, the second effect offsets the first one.[28]

[28] Of course, if the supplementary fines can be made arbitrarily large, incentive problems disappear and the full-information outcome (no rent for the firm and thus no collusive stakes) can be implemented. Note also that if the firm's profit and the supervisors' utilities are weighed differently in the social objective, then it might become optimal not to set some of the penalties at their highest value; this might shed light on Congress' choice during the 1988 Amendments of the Price-Anderson Act to impose civil penalties for violations of nuclear safety requirements but not to remove the indemnification in the event of a nuclear accident (the latter option being favored by D.O.E.).

Giving the ex post monitor the possibility to impose a supplementary fine when his investigation unveils a negligent behavior allows now to increase fines beyond the regulatory punishments. The firm's rent, and consequently the ex ante collusive stake, depend now on the frequency of an ex post investigation. This calls for a strictly positive probability of such investigation, even under integration.

However, the possibility of ex post collusion must also be taken into account. If the ex post monitor conceals the result of his investigation, the firm avoids paying the corresponding extra fine. There is now a strictly positive ex post stake of collusion at equilibrium, i.e., $\hat{\tau}^l_{\text{post}} = t^l_a + w + \Delta_{\text{post}} = \Delta_{\text{post}}$, $l \in \{I, S\}$. Notice that this collusive stake is the same under integration and separation.

The possibility of raising fines ex post increases the scope for separation. Comparing the bribe imposed by the the ex ante monitor in the different institutional arrangements, we obtain (where $\hat{\tau}^l_{\text{ante}}$, $l \in \{I, S\}$ denotes the ex ante collusive bribe):

$$\begin{aligned}
[\pi_0 + (1-\pi_0)(1-q\varepsilon_j)]\hat{\tau}^S_{\text{ante}} &= \hat{\tau}^I_{\text{ante}} - q\varepsilon_j(1-\pi_0)(t^S_a + w) - (1-\pi_0)q\varepsilon_j\Delta_{\text{post}}, \\
&= \hat{\tau}^I_{\text{ante}} - (1-\pi_0)q\varepsilon_j\Delta_{\text{post}} < \hat{\tau}^I_{\text{ante}}.
\end{aligned}$$

The expected bribe under separation is now strictly smaller than under integration. Indeed, under separation, the ex ante monitor must account for the fact that, if he colludes with the firm, the ex post monitor will impose an additional punishment Δ_{post} with probability $(1-\pi_0)q\varepsilon_j$. By contrast, under integration, if a long term collusion occurs with the monitor, the firm is immunized against the threat of ex post supplementary fines and is thus willing to pay a larger bribe. Hence, even when transaction costs are linear and monitors only care about expected bribes, the possibility of ex post supplementary fines strictly favors separation.

7 Self-Enforcing Collusion

So far we have considered that, if the merged monitor colludes at the ex ante stage, he is also committed to collude in the event of an ex post investigation. Integration also comes with a commitment to enforce a long-term collusion between the firm and the monitor.

We now relax this assumption and consider a weaker collusive behavior with imperfect commitment. That collusion is now self-enforcing opens new possibilities to fight collusion under integration. The case of separation is left unchanged since the various investigations are undertaken by different agents.

In our context, collusion is self-enforcing if, following a successful ex ante investigation and the acceptance of a side-contract, the merged entity does not find it worth to reveal evidences if an ex post investigation has been called for and is successful.[29]

As before, the incentive transfers offered to the firm in a collusion-free equilibrium are still given by $\{t_a^I, t_n^I\}$. This remark allows us to simplify the collusion-proofness constraints that we now derive.

Ex Post Collusion under Integration. Consider that no information has been learned ex ante. The ex post monitor has no incentives to collude with the firm if the following ex post collusion-proofness constraints are satisfied:

$$V_{\text{post}}^I, \tilde{V}_{\text{post}}^I \geq k(t_a^I + w) = 0. \qquad (\tilde{CP}_{\text{post}}^I)$$

Again ex post collusion proofness is costless to achieve.

Ex Ante Collusion under Integration. Self-enforceability of an ex ante collusive agreement is akin to a requirement of perfection in the collusive sub-game starting ex post, once an ex post investigation is run and successful. This means that the merged entity must receive a bribe large enough upon a successful ex post investigation that he still keeps on hiding evidences on misconduct.

The optimal self-enforcing ex ante collusion corresponds thus to bribes $\{\tau_n^I, \tau_{a1}^I, \tau_{a2}^I\}$ which solve now:

$$\begin{aligned}
&\max_{\{\tau_n,\tau_{a1},\tau_{a2}\}} \left\{\pi_0(t_n^I - \tau_n) + (1-\pi_0)(1-q\varepsilon_j)(t_a^I - \tau_{a1}) + (1-\pi_0)q\varepsilon_j(t_a^I - \tau_{a2})\right\}, \\
&\text{s.t. } (LT^I): \pi_0 k(\tau_n) + (1-\pi_0)(1-q\varepsilon_j)k(\tau_{a1}) + (1-\pi_0)q\varepsilon_j k(\tau_{a2}) \geq V_{\text{ante}}^I, \\
&\qquad (ST^I):\ k(\tau_{a2}) \geq \tilde{V}_{\text{post}}^I,
\end{aligned}$$

Constraint (ST^I) expresses the fact that an ex ante collusive agreement must now also prevent a deviation by the monitor ex post. Constraint (LT^I) simply states that the monitor's gain from accepting the collusive side-contract must be greater than what he gets if he reveals immediately his information. The optimal side-contract will be different depending on whether (ST^I) binds or not.

Case 1. (LT^I) only is binding. This arises when $k(\tau_{\text{ante}}^I) = V_{\text{ante}}^I > \tilde{V}_{\text{post}}^I$.

Case 1 coincides with the case of integration already studied in Section 4. The cost of ensuring collusion-proofness is thus $V_1^I(p,q) = V^I(p,q)$. The monitor is compensated only if he reveals valuable information on the firm's effort at the ex ante stage. Graphically, the optimal outcome in this class of mechanisms coincides with Point C in Figure 1.

Case 2. (ST^I) and (LT^I) are both binding when $V_{\text{ante}}^I \leq \tilde{V}_{\text{post}}^I$.

Note that $\tilde{V}_{\text{post}}$ is now positive. This might make attractive for the monitor to delay the revelation of information acquired ex ante to get a higher ex post wage if an ex post

[29]Note that we still assume that side-transfers within each period are enforced, i.e., if the integrated monitor hides informative signals at the ex ante audit stage, the firm still gives the corresponding bribe.

investigation is called upon. This would be the case if $V^I_{\text{ante}} < (1-\pi_0)q\varepsilon_j \tilde{V}^I_{\text{post}}$. In that case, the side-contract such that $\tau_n = \tau_{a_1} = 0$[30] and $\tau_{a_2} = k^{-1}(\tilde{V}^I_{\text{post}})$ satisfies (LT^I) and (ST^I) so that the firm does not even have to bribe the regulator for enjoying his hiding information.

Inducing early detection of misconduct and enforcement of a standard is of course socially valuable when D is large enough since such enforcement reduces the probability of an accident. Henceforth, we shall restrict the analysis to wages satisfying:

$$V^I_{\text{ante}} \geq (1-\pi_0)q\varepsilon_j \tilde{V}^I_{\text{post}}.$$ [31]

The ex ante collusion-proofness constraint is now given by:

$$[1-(1-\pi_0)q\varepsilon_j]k^{-1}\left(\frac{V^I_{\text{ante}} - (1-\pi_0)q\varepsilon_j \tilde{V}^I_{\text{post}}}{1-(1-\pi_0)q\varepsilon_j}\right) + (1-\pi_0)q\varepsilon_j k^{-1}\left(\tilde{V}^I_{\text{post}}\right) \geq \frac{\pi_1\psi}{\Delta\pi + \pi_0 p\varepsilon_r}. \quad (\tilde{CP}^I_{\text{ante}})$$

Taking into account Cases 1 and 2, the constrained set is the shaded area on Figure 1.

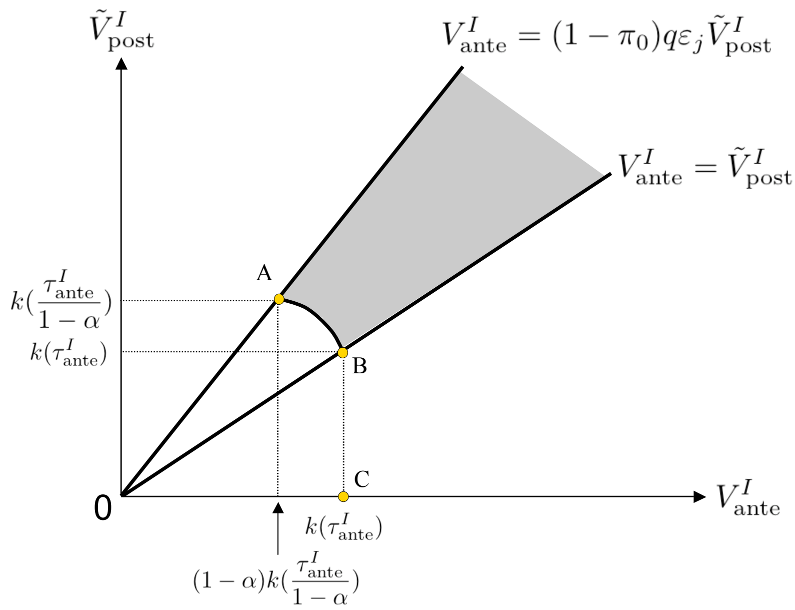

Figure 1: Self-Enforcing Collusion: The Constrained Set (with $\alpha \equiv 1-(1-\pi_0)q\varepsilon_j$).

Only for Case 2 may we get something different from the case of an enforceable collusion. Within the class of incentives schemes which play on the self-enforceability of the

[30] Restricting attention of course to positive bribes.

[31] Note that this constraint also implies that the monitor does not delay information revelation *on* the equilibrium path, i.e., when the firm exerts effort $e = 1$.

collusion, the optimal one must solve:

$$\min_{\{V^I_{\text{ante}}, \tilde{V}^I_{\text{post}}, V^I_{\text{post}}\}} \left\{ p\varepsilon_r V^I_{\text{ante}} + p(1-\varepsilon_r)(1-\pi_1)q\varepsilon_j \tilde{V}^I_{\text{post}} + (1-p)(1-\pi_1)q\varepsilon_j V^I_{\text{post}} \right\},$$

$$\text{s.t. } (\tilde{CP}^I_{\text{ante}}),\ (\tilde{CP}^I_{\text{post}}),\ (IR_i), (1-\pi_0)q\varepsilon_j \tilde{V}^I_{\text{post}} \leq V^I_{\text{ante}} \leq \tilde{V}^I_{\text{post}}.$$

Note that $k^{-1}(\cdot)$ is convex and that one minimizes a linear function. The optimum within Case 2-mechanisms is thus achieved at an extremal point of the constrained set, i.e., either at point A or point B.

The next proposition finds conditions such that this extremal point is at $V^I_{\text{ante}} = \tilde{V}^I_{\text{post}}$ (Point B in Figure 1). Undermining collusive deals by playing on their self-enforceability requires then to give a positive wage to the merged entity ex post: $V^I_{\text{ante}} = \tilde{V}^I_{\text{post}} = k(\tau^I_{\text{ante}})$. This is clearly too costly from a social point of view. One can as well prevent collusion by giving the same ex ante wage upon an ex ante investigation as if collusion was enforceable and giving no ex post wage.

We can thus state the following proposition.

Proposition 8 *Assume that*

$$[\varepsilon_r + (1-\varepsilon_r)(1-\pi_1)q\varepsilon_j]k(\tau^I_{ante}) < [\varepsilon_r(1-\pi_0) + (1-\varepsilon_r)(1-\pi_1)]q\varepsilon_j k\left(\frac{\tau^I_{ante}}{(1-\pi_0)q\varepsilon_j}\right), \quad (6)$$

a condition which always holds for ε_r small enough. Then, the fact that collusion is self-enforcing does not impact on social welfare under integration. Separation still dominates integration.

By contrast, assume now that ε_r is sufficiently large (e.g., close to 1), so that Condition (6) no longer holds. Considering only Case 2, Point A is then preferred to Point B.

Let us find the conditions under which Point A is also preferred to Point C. Exploiting the self-enforceability of collusion allows to reduce the wage V^I_{ante} but forces to give a positive wage $\tilde{V}^I_{\text{post}}$. This has a low cost when ε_r is high enough. Integration may then dominate separation. When the probability ε_j of an ex post successful investigation is small, raising $\tilde{V}_{\text{post}}$ has little impact on welfare and undermines significantly collusion at the ex ante stage. Under separation, such effect is absent. The ex ante collusive deal is no longer under the threat of an ex post deviation by the monitor as under integration.

Proposition 9 *Assume that* (6) *is not satisfied (i.e., ε_r is large enough) and that*

$$[\varepsilon_r(1-\pi_0) + (1-\varepsilon_r)(1-\pi_1)]q\varepsilon_j k\left(\frac{\tau^I_{ante}}{(1-\pi_0)q\varepsilon_j}\right) < \varepsilon_r[1-(1-\pi_0)q\varepsilon_j]k\left(\frac{\tau^I_{ante}}{1-(1-\pi_0)q\varepsilon_j}\right),$$

a condition which holds when ε_j low enough and ε_r is high enough. Then, integration dominates separation if collusion is self-enforcing.

8 Conclusion

This paper has highlighted the benefits of splitting ex ante and ex post monitoring of the firm's effort in safety care in a moral hazard environment. The ex post intervention by an independent monitor makes more difficult the collusive deals that an ex ante monitor can strike with the firm. This makes regulatory capture less of a concern. Even though relying on ex post monitoring is inefficient when capture is not a concern, it really improves social welfare otherwise as long as collusive norms are strong enough.

One criticism of our approach is that it relies on an assumption, convexity of the transaction costs of side-contracting which may be hard to ascertain in practice. Three responses can be made to that criticism. The first one is that this assumption provides a nice and tractable allegory to capture the simple and intuitive fact that, as a regulator and a firm have more points of contact, they find it easier to reach efficient collusive deals.[32] The second one is more pragmatic. If one admits that collusive side-contracts suffer from technological frictions, it is interesting to understand the consequences for institutional design of making specific assumptions on these frictions. Lastly, this assumption can also be viewed as a convenient black-box for the insurance concerns that would arise in a less tractable model where the firm would be risk-averse.

Although our model already generates a value for separation, it is also worth stressing other potential benefits of this latter institutional choice. Separation may help to generate hard evidences even when there are none.[33] When forging evidences is possible for the monitors, the duplication of expertise even when the ex ante investigation reveals a high effort level might be warranted. Separation allows indeed to cross-check the monitors' announcements. If the ex ante monitor can be punished when caught colluding, then, by splitting the monitory tasks, it becomes possible to detect with a non-zero probability that the ex ante monitor has colluded with the firm and to further reduce the expected cost of collusion-proofness with respect to the integration case. The scope for separation increases with cross-checking.[34]

Also, duplication of expertise between the ex ante and the ex post monitors may help them to specialize in gathering information on different dimensions of the firm's activities. For instance, the ex ante regulator could prefer gathering technical information whereas ex post judges would instead focus on testimonies by private parties. This specialization issue was put aside in our modelling since both monitors could only generate information on

[32]Of course, other modelling devices could give us similar outcomes. Repeated interactions could, with the help of the modelling technology available from repeated games, give another way.

[33]Consider for instance that the signal obtained by the ex ante monitor perfectly reveals the true effort level exerted by the firm, i.e., $\varepsilon_r = 1$. In that case, if the ex ante supervisor wants to collude with the firm when he has observed $\sigma_r = 0$, he must falsify (maybe at a cost) his report and claim $\sigma_r = 1$.

[34]For a similar argument, see Laffont (2000).

the same aspect of the firm's activities. Investigating both the incentives for specialization and its consequences for institutional design would be a valuable extension.

From a theoretical point of view, our approach differs significantly from other studies of corruption in regulation or law enforcement which have stressed the equilibrium nature of corruption.[35] In our paper, collusion is prevented by an adequate design of incentive rewards[36] and comparison between institutions amounts to minimizing the cost of preventing collusion. It would be interesting to investigate environments where collusion would be an equilibrium phenomenon. This could be easily achieved by introducing some non-observable heterogeneity among monitors, for instance, in terms of how eager to collude they are.[37] How institutions change the equilibrium level of corruption is then an important topic that would be worth studying.

It is remarkable that our result on the benefits of separation takes as *fixed* the transaction costs of side-contracting when the institutional environment changes. The existing frictions encapsulated into the $k(\cdot)$ function depend of course of the various norms for collusive behavior that may establish and how strong they are. Scholars in Public Administration have long emphasized that these norms are key to understand how institutions function and evolve.[38] While our analysis unveils that norms of behavior impact both the incentives and the design of institutions, the research agenda should develop a theory of how incentives and institutions shape in turn norms of behavior.

Taking a broader perspective, the complementarity between regulation and legal investigations in environmental policies highlighted by this model could probably be extended to other fields; one could for instance think of antitrust versus regulatory policies. We plan to investigate some of these issues in future research.

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[35] See Becker and Stigler (1974), Mookherjee and P'Ng (1995), Garoupa (1997) and Polinsky and Shavell (2001).

[36] And it is optimal to do so.

[37] See Tirole (1992) for such a model.

[38] See Barnard (1938).

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Appendix

Proof of Proposition 2

Once the transfers are determined, the bribe in the event of successful ex ante investigation is given by $\tau^I_{\text{ante}} = \frac{\pi_1 \psi}{\Delta\pi + \pi_0 p \varepsilon_r} > 0$. Taking into account the possibility of a corner solution at zero, the optimal probability of ex ante monitoring is thus given by:

$$C_r'(p^I) = \max\left\{ \frac{\varepsilon_r \pi_1^2 \psi}{(\Delta\pi + \pi_0 p^I \varepsilon_r)^2} + \varepsilon_r \left[\frac{\pi_0 p^I \varepsilon_r}{\Delta\pi + \pi_0 p^I \varepsilon_r} \tau^I_{\text{ante}} k'(\tau^I_{\text{ante}}) - k(\tau^I_{\text{ante}}) \right], 0 \right\}.$$

To quantity the two effects note that we have:

$$\frac{\pi_0 p^I \varepsilon_r}{\Delta\pi + \pi_0 p^I \varepsilon_r} \tau^I_{\text{ante}} k'(\tau^I_{\text{ante}}) - k(\tau^I_{\text{ante}}) < \tau^I_{\text{ante}} k'(\tau^I_{\text{ante}}) - k(\tau^I_{\text{ante}}) < 0,$$

because $k(\cdot)$ is concave and $k(0) = 0$. Henceforth, the direct effect of a reduction in the probability of an ex ante investigation always dominates the indirect effect.

The second-order condition is satisfied if $C_r(.)$ is sufficiently convex.

Proof of Proposition 4

The optimal probabilities of monitoring under separation are characterized by the following conditions:

$$C_r'(p^S) = \max\left\{\frac{\varepsilon_r \pi_1^2 \psi}{(\Delta\pi + \pi_0 p^S \varepsilon_r)^2} + \varepsilon_r \left[\frac{\pi_0 p^S \varepsilon_r}{\Delta\pi + \pi_0 p^S \varepsilon_r}\alpha(q)\tau^S_{\text{ante}} k'(\tau^S_{\text{ante}}) - \alpha(q)k(\tau^S_{\text{ante}})\right], 0\right\} \tag{7}$$

$$C_j'(q^S) = p^S \varepsilon_r (1-\pi_0)\varepsilon_j \left[k(\tau^S_{\text{ante}}) - \tau^S_{\text{ante}} k'(\tau^S_{\text{ante}})\right] \tag{8}$$

where $\tau^S_{\text{ante}} = \frac{\tau^I_{\text{ante}}}{\alpha(q)}$ and $\alpha(q) = \pi_0 + (1-\pi_0)(1-q\varepsilon_j)$.

The second-order conditions are satisfied if $C_r(.)$ and $C_j(.)$ are sufficiently convex.

Note first that $q^S \geq 0$ since $k(\tau^S) - \tau^S k'(\tau^S)$ is strictly increasing for $\tau^S \geq 0$ and equal to 0 for $\tau^S = 0$.

Second, let us compare p^I and p^S. Consider the function: $f(\alpha) = \frac{\pi_0 p \varepsilon_r}{\Delta\pi + \pi_0 p \varepsilon_r}\tau^I_{\text{ante}} k'(\frac{\tau^I_{\text{ante}}}{\alpha}) - \alpha k(\frac{\tau^I_{\text{ante}}}{\alpha})$ defined for $\alpha \geq 0$. If $f'(\alpha) \leq 0$ for all relevant values of α, then $p^S \geq p^I$ since the marginal benefit associated to the ex ante investigation is larger under separation than under integration. Simple manipulations show that: $f'(\alpha) = -k(\frac{\tau^I_{\text{ante}}}{\alpha}) + \frac{\tau^I_{\text{ante}}}{\alpha} k'(\frac{\tau^I_{\text{ante}}}{\alpha}) - \frac{\pi_0 p \varepsilon_r}{\Delta\pi + \pi_0 p \varepsilon_r}(\frac{\tau^I_{\text{ante}}}{\alpha})^2 k''(\frac{\tau^I_{\text{ante}}}{\alpha})$. Under the assumption that $k'''(.) \geq 0$ and $p\varepsilon_r \leq \frac{\Delta\pi}{\pi_0}$ (which obviously holds when $\Delta\pi > \pi_0$), one can immediately show that $f''(\alpha) > 0$; since $\lim_{\alpha\to+\infty} f'(\alpha) = 0$, we have $f'(\alpha) < 0$ for all relevant values of α.

Proof of Proposition 5

Let us suppose that the firm is now risk-averse having a von Neuman-Morgenstern utility function over monetary gains $u(\cdot)$ with $u' > 0$, $u'' < 0$. We denote by $h = u^{-1}$ the inverse function of u. The firm's incentive and participation constraints are now given by:

$$\begin{aligned}\pi_1 u(t_n) + (1-\pi_1)u(t_a) - \psi &\geq p\varepsilon_r[u(-w) - \psi] \\ &+ (1-p\varepsilon_r)[\pi_0 u(t_n) + (1-\pi_0)(1-q\varepsilon_j)u(t_a) + (1-\pi_0)q\varepsilon_j u(-w)], \quad (IC)\end{aligned}$$

$$\pi_1 u(t_n) + (1-\pi_1)u(t_a) - \psi \geq 0. \qquad (IR)$$

Integration. Under integration, an optimal side-contract when $\sigma_r = 0$ has been observed must solve:

$$\max_{\{\tau_n, \tau_{a1}, \tau_{a2}\}} \left\{\pi_0 u(t_n - \tau_n) + (1-\pi_0)(1-q\varepsilon_j)u(t_a - \tau_{a1}) + (1-\pi_0)q\varepsilon_j u(t_a - \tau_{a2})\right\},$$
$$\text{s.t. } \pi_0\tau_n + (1-\pi_0)(1-q\varepsilon_j)\tau_{a1} + (1-\pi_0)q\varepsilon_j\tau_{a2} \geq V^I_{\text{ante}}.$$

At the optimum of this problem, the bribe scheme should provide full insurance to the firm: $t_n - \tau_n = t_a - \tau_{a1} = t_a - \tau_{a2}$. Therefore, the collusion-proofness constraint writes as:

$$V^I_{\text{ante}} \geq \pi_0 t_n + (1-\pi_0)t_a - h(u(-w) - \psi). \tag{9}$$

If the ex ante investigation has not been undertaken or has not been successful, it remains the possibility of colluding ex post and the optimal side-contract solves then:

$$\max_{\tau_{a3}} u(t_a - \tau_{a3}) \text{ s.t. } \tau_{a3} \geq V^I_{\text{post}},\ \tilde{V}^I_{\text{post}}.$$

This yields a bribe $\tau_{a3} = V^I_{\text{post}},\ \tilde{V}^I_{\text{post}}$, and an ex post collusion-proofness constraint:

$$\tilde{V}^I_{\text{post}},\ V^I_{\text{post}} \geq t_a + w. \tag{10}$$

In order to streamline the analysis, we set $\tilde{V}^I_{\text{post}} = V^I_{\text{post}}$.

Hence, under integration, the cost of achieving a collusion-proof regulatory scheme is given by:

$$V^I = p\varepsilon_r V^I_{\text{ante}} + (1 - p\varepsilon_r)(1-\pi_1)q\varepsilon_j V^I_{\text{post}}.$$

For fixed audit probabilities, the cost of implementing a high level of care in a collusion-proof way under integration is thus defined as follows:

$$\begin{aligned}\mathcal{C}^I(p,q) = &\min_{\{t_n, t_a, V^I_{\text{ante}}, V^I_{\text{post}}\}} \left\{\pi_1 t_n + (1-\pi_1)t_a + C_r(p) + C_j(q) + V^I\right\}, \\ &\text{s.t. } (LL),\ (IR),\ (IC),\ (9) \text{ and } (10).\end{aligned}$$

Separation. Under separation instead, the optimal ex ante side-contract between the regulator and the firm must solve:

$$\begin{aligned}&\max_{\{\tau_n, \tau_{a1}\}} \{\pi_0 u(t_n - \tau_n) + (1-\pi_0)(1-q\varepsilon_j)u(t_a - \tau_{a1}) + (1-\pi_0)q\varepsilon_j u(-w)\} \\ &\text{s.t. } \pi_0\tau_n + (1-\pi_0)(1-q\varepsilon_j)\tau_{a1} \geq V^S_{\text{ante}}.\end{aligned}$$

At the optimum, the bribes are such that $t_n - \tau_n = t_a - \tau_{a1}$. The ex ante collusion-proofness constraint writes as follows:

$$\begin{aligned}V^S_{\text{ante}} \geq\ &\pi_0 t_n + (1-\pi_0)(1-q\varepsilon_j)t_a \\ &- [\pi_0 + (1-\pi_0)(1-q\varepsilon_j)]h\left(u(-w) - \frac{\psi}{\pi_0 + (1-\pi_0)(1-q\varepsilon_j)}\right).\end{aligned} \tag{11}$$

The ex post collusion-proofness constraints are defined as follows:

$$\tilde{V}^S_{\text{post}},\ V^S_{\text{post}} \geq t_a + w. \tag{12}$$

Again, in order to streamline the analysis, we set $\tilde{V}^S_{\text{post}} = V^S_{\text{post}}$.

Under separation, the cost of achieving a collusion-proof regulatory scheme is:

$$V^S = p\varepsilon_r V^S_{\text{ante}} + (1 - p\varepsilon_r)(1 - \pi_1)q\varepsilon_j V^S_{\text{post}}.$$

For fixed investigation probabilities, the optimal collusion-proof policy solves:

$$\mathcal{C}^S(p,q) = \min_{\{t_n, t_a, V^S_{\text{ante}}, V^S_{\text{post}}\}} \left\{\pi_1 t_n + (1-\pi_1)t_a + C_r(p) + C_j(q) + V^S\right\},$$
$$\text{s.t. } (LL),\ (IR),\ (IC),\ (11) \text{ and } (12).$$

Comparison. Without solving for these problems and answering the questions of which constraints are indeed binding note that the cost of achieving a collusion-proof policy is lower under separation. Indeed, define $\tilde{V}^S$ and $\tilde{V}^I$ as follows:

$$\tilde{V}^S = \min_{\{V^S_{\text{ante}}, V^S_{\text{post}}\}} V^S$$
$$\text{s.t. } (11) \text{ and } (12)$$

and

$$\tilde{V}^I = \min_{\{V^I_{\text{ante}}, V^I_{\text{post}}\}} V^I$$
$$\text{s.t. } (9) \text{ and } (10).$$

Then $\tilde{V}^S < \tilde{V}^I$ since $t_a \geq -w$, $h(u(-w)) = -w$ and we have:

$$[\pi_0 + (1-\pi_0)(1-q\varepsilon_j)]h\left(u(-w) - \frac{\psi}{\pi_0 + (1-\pi_0)(1-q\varepsilon_j)}\right) + (1-\pi_0)q\varepsilon_j h(u(-w)) > h(u(-w)-\psi)$$

for $h(\cdot)$ strictly convex from Jensen's inequality.

Proof of Proposition 6

The analysis is undertaken considering the integration case. The separation case follows a similar logic. Consider that ex ante fines are such that $t_n - F^n_r = -w + dF_1$, $t_a - F^a_r = -w + dF_2$, $t_a - F^a_j = -w + dF_3$.

The first part of the analysis proceeds in a similar way as in Section 4; we only provide the relevant steps. Under the new system of fines, the ex ante transfers are given by: $t_a = t^I_a$ and $t_n = t^I_n + \frac{\pi_1 p\varepsilon_r dF_1 + (1-\pi_1)p\varepsilon_r dF_2 + (1-\pi_0)(1-p\varepsilon_r)q\varepsilon_j dF_3}{\Delta\pi + \pi_0 p\varepsilon_r}$. For fixed audit probabilities, the rent of the firm is thus given by:

$$\mathcal{U} = \mathcal{U}^*(p) + \frac{\pi_1\left[\pi_1 p\varepsilon_r dF_1 + (1-\pi_1)p\varepsilon_r dF_2 + (1-\pi_0)(1-p\varepsilon_r)q\varepsilon_j dF_3\right]}{\Delta\pi + \pi_0 p\varepsilon_r},$$

which is increasing in dF_1, dF_2 and dF_3.

The firm's gain if the monitor rejects the collusive offer is thus: $\pi_1(-w + dF_1 - \psi) + (1-\pi_1)(1-q\varepsilon_j)(-w+dF_2-\psi)+(1-\pi_1)q\varepsilon_j(-w+dF_2-\psi) = -w-\psi+\pi_1 dF_1+(1-\pi_1)dF_2$. The ex ante flat bribe is therefore given by:

$$\tau_{\text{ante}} = \tau^I_{\text{ante}} + \frac{1}{\Delta\pi + \pi_0 p\varepsilon_r}\left[-\pi_1\Delta\pi dF_1 - (1-\pi_1)\Delta\pi dF_2 + \pi_0(1-\pi_0)(1-p\varepsilon_r)q\varepsilon_j dF_3\right],$$

which is decreasing in dF_1 and dF_2 but increasing in dF_3.

The ex post bribe is $\tau_{\text{post}} = 0$ since the firm obtains a higher gain when the auditor reveals than when it conceals the information, i.e., $t_a - \tau_{\text{post}} = -w - \tau_{\text{post}} \leq -w + dF_3$, $\forall \tau_{\text{post}} \geq 0$. Therefore as soon as dF_3 is positive, there are no ex post collusive stakes. Since the firm's gain and the ex ante collusive stake are both increasing in dF_3, it is optimal to set $dF_3 = 0$.

In a second step, still considering the audit probabilities as fixed and given that $dF_3 = 0$, we are looking for the system of fines $\{dF_1, dF_2\}$ which solves:

$$\min_{\{dF_1, dF_2\}} \{\mathcal{C} = \mathcal{U} + p\varepsilon_r k(\tau_{\text{ante}}) + (1-p\varepsilon_r)(1-\pi_1)q\varepsilon_j k(\tau_{\text{post}})\}$$

Straightforward computations show that $\mathcal{C}$ is concave in dF_1 and dF_2 so that the corresponding penalties will always be set either at the highest or the lowest admissible value. We have:

$$\frac{\partial \mathcal{C}}{\partial dF_1} \propto \pi_1 - \Delta\pi k'(\tau_{\text{ante}}) > 0,$$

since $k(0) = 0$, $k(.)$ increasing concave and $k(x) \leq x$ $\forall x$ imply that $k'(.) \leq 1$. Thus it is optimal to set $dF_1 = 0$, whatever the audit probabilities. Similar computations lead to $dF_2 = 0$.

Proof of Proposition 7

Simple manipulations show that the firm's gain is given by:

$$\mathcal{U}'(p,q) = \mathcal{U}(p) - \pi_1 \frac{p\varepsilon_r\Delta_{\text{ante}} + (1-\pi_0)(1-p\varepsilon_r)q\varepsilon_j\Delta_{\text{post}}}{\Delta\pi + \pi_0 p\varepsilon_r};$$

the collusive stakes are now given by:

$$\begin{aligned}
\tau^{I'}_{\text{ante}} &= \tau^I_{\text{ante}} + \frac{\Delta\pi\Delta_{\text{ante}} - \pi_0(1-\pi_0)(1-p\varepsilon_r)q\varepsilon_j\Delta_{\text{post}}}{\Delta\pi + \pi_0 p\varepsilon_r},\\
\tau^{S'}_{\text{ante}} &= \tau^S_{\text{ante}} + \frac{\Delta\pi\Delta_{\text{ante}} - \pi_1(1-\pi_0)q\varepsilon_j\Delta_{\text{post}}}{(\Delta\pi + \pi_0 p\varepsilon_r)[\pi_0 + (1-\pi_0)(1-q\varepsilon_j)]},\\
\tau^{I'}_{\text{post}} &= \tau^{S'}_{\text{post}} = \Delta_{\text{post}}.
\end{aligned}$$

The ex post stake of collusion is now strictly positive.

The probability of an ex post investigation depends on its impact (i) on the firm's rent, (ii) on the ex ante collusive stake, (iii) on the ex post collusive stake and (iv) on the cost of this investigation.

The optimal levels of supplementary fines solve:

$$\min_{\{\Delta_{\text{ante}},\Delta_{\text{post}}\}} \left\{\mathcal{U}'(p,q) + p\varepsilon_r k(\tau^l_{\text{ante}}) + (1-p\varepsilon_r)(1-\pi_1)q\varepsilon_j k(\tau^l_{\text{post}})\right\},$$

with $l \in \{I, S\}$. Optimizing with respect to Δ_{ante} and using the fact that $k'(.) \leq 1$, we show immediately that the supplementary fine in the event of an ex ante investigation must be set at the highest possible value. A similar reasoning holds for Δ_{post}.

Finally, cumbersome computations show that the difference between the expected cost of collusion-proofness under integration, denoted by $V^{I'}$, and under separation, denoted $V^{S'}$, is given by:

$$\Delta V' \equiv V^{I'} - V^{S'} = p\varepsilon_r \left[k(\alpha\tilde{\tau}) - \alpha k\left(\tilde{\tau} - \frac{1-\alpha}{\alpha}\Delta_{\text{post}}\right)\right],$$

where $\tilde{\tau} = \tau^S_{\text{ante}} + \frac{\Delta\pi\Delta_{\text{ante}}}{[\pi_0+(1-\pi_0)(1-q\varepsilon_j)][\Delta\pi+\pi_0 p\varepsilon_r]} - \frac{\pi_0(1-\pi_0)(1-p\varepsilon_r)q\varepsilon_j\Delta_{\text{post}}}{\pi_0+(1-\pi_0)(1-q\varepsilon_j)}$ and $\alpha = [\pi_0+(1-\pi_0)(1-q\varepsilon_j)]$. Since $k(.)$ is increasing, we have: $k(\alpha\tilde{\tau}) - \alpha k(\tilde{\tau} - \frac{1-\alpha}{\alpha}\Delta_{\text{post}}) \geq k(\alpha\tilde{\tau}) - \alpha k(\tilde{\tau}) \geq 0$ since $k(.)$ concave.

Proof of Proposition 9

Denote by $V^I_A(p,q)$ the expected cost of collusion-proofness when the optimal extremal point is point A. Then, we have:

$$V^S(p,q) - V^I_A(p,q)\big|_{\varepsilon_r\approx 1^-} \propto (1-(1-\pi_0)q\varepsilon_j)k\left(\frac{\tau^I_{\text{ante}}}{1-(1-\pi_0)q\varepsilon_j}\right) - (1-\pi_0)q\varepsilon_j k\left(\frac{\tau^I_{\text{ante}}}{(1-\pi_0)q\varepsilon_j}\right),$$

which is positive when ε_j is low enough.