PARIS SCHOOL OF ECONOMICS
ECOLE D'ECONOMIE DE PARIS

WORKING PAPER N° 2009 - 20

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

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3rd July 2009

Abstract

When a firm undertakes risky activities, the conflict between social and private incentives to exercise safety care requires public intervention. This control takes the form of both monetary incentives but also monitoring taking place either ex ante or ex post, i.e., before or after an accident occurs. We delineate the respective scopes of these monitoring activities when public monitors are either benevolent or corruptible. Separation between the ex ante and the ex post monitors helps to prevent capture, increases the likelihood of ex post investigation and improves welfare.

Keywords. Risk regulation, monitoring, capture, integration and separation.

JEL Classification. L51.

*Financial and intellectual support from the French Ministry of Ecology and Sustainable Development are acknowledged. We are grateful to Bernard Caillaud, Giacinta Cestone, David Encaoua, David Ettinger, Jean-Pierre Ponssard, Bernard Salanié, Jean Tirole and participants at various seminars for helpful comments. All errors are ours.

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1 Introduction

Although much debated and often criticized, the view that our societies are 'at risk'[1] has certainly pushed both scholars and practitioners to reconsider the role of public intervention in the field of risk regulation.[2] Consumers should be prevented from buying defective products, workers should be protected from accidents on the workplace, medical malpractices should be avoided to protect patients' health, the environment should be sheltered from major industrial or transportation hazards, etc. In all these circumstances and although risk tolerance may vary across countries and policy domains, public intervention is called for to control private actors involved in activities that put humans or the environment at risk. As risks spread over the whole spectrum of economic activities, more effort and expertise should be allocated to assess their true impact on society. The adequate design of incentives for key players involved in this management of risks should be put at the forefront of the public debate.

Maintaining risk at levels which are socially acceptable certainly requires systems of control. This issue has attracted much attention in the public management literature with a strong motivation being to explain the great variety of regimes in risk regulation both across fields and countries.[3] However, little is known on the design of adequate institutions for risk regulation. This design varies significantly from one domain to the other. Casual evidence shows that, sometimes, administrative agencies are staffed with experts knowledgeable in assessing specific risks and these agencies have strong enforcement powers. A typical example in order is given by nuclear power plants which are routinely checked for maintaining safety. In other regulated fields like defective products, agencies are more generalist and most of the effective enforcement power is rather left to Courts of Law that perform their own investigation in case of prosecution following an accident. Most of the time however, risk regulation is an intricate web of both kinds of intervention taking place either ex ante or ex post. Transportation, road and navigation safety, or occupational safety are good illustrations.

One could a priori think that risk regulation has no specific features and that the grid already available to discuss regulatory policies and institutions for market regulation remains valid.[4] There is actually some value in distinguishing agencies and regulations which are used ex ante, i.e. before any accident realizes, from agencies, Courts of Law and other enforcement devices which may appear ex post, i.e. after an accident. This time line naturally distinguishes the roles of different public officials involved in risk monitoring.

In this respect, an important but by large unexplored issue is to delineate the respective scopes of ex ante and ex post control in a world plagued with informational constraints. This paper discusses the costs and benefits of splitting the ex ante and the ex post monitoring of a firm whose activity generates some risk. This is done in a context where moral hazard on safety care calls for explicit monetary incentives but also for setting up

[1]Beck (1992).

[2]For instance, Hood, Rothstein and Baldwin (2000) recognized that "The idea of the 'regulatory state' is that a new institutional and policy style has emerged, in which government's role as a regulator advances (...)".

[3]Hood, Rothstein and Baldwin (2001) and Power (1997).

[4]Noll (1989) and Baron (1989).

auditing devices to force compliance with safety standards. When capture of monitors by the very interests they are supposed to control is a concern, separation of monitoring tasks between two independent bodies dominates.

Overview of the model. Consider a risk-neutral firm which can provoke an accident of substantial scale affecting third-parties. This firm undertakes a nonverifiable prevention effort. A high level of effort is socially optimal and must be implemented. Compliance with this standard of due care can be induced through monetary incentives and the threat of monitoring upon random inspections. Monitoring takes place either ex ante or ex post following an accident and uncovers whether the firm has performed sufficient care. Fines can be imposed if investigation reveals misconduct, though the firm is protected by limited liability. This access to privileged information gives discretion to public officials. The firm wants to capture monitors to prevent them from revealing its misbehavior.

Had monitors been non-corruptible, monitoring would unambiguously improve the firm's incentives. Things are different when monitors are corruptible.

Consider first the case where ex ante and ex post monitors are merged into a single entity. Such an integration opens large possibilities for collusion. The long-term relationship between an integrated monitor and the firm facilitates collusion by expanding the set of contingencies where bribes can be exchanged. Under integration, the monitor can take advantage of his close contact with the firm to significantly reduce the transaction costs of side-contracting. Postulating convex transaction costs in the technology for exchanging side-transfers, average transaction costs decrease as bribes are smoothed over more contingencies.[5] Intervening both ex ante and ex post, a merged agency reduces such transaction costs and reaches more efficient collusive deals with the regulated firm.

Under separation, different monitors are used ex ante and ex post. Each monitor anticipates that the other receives enough benefits from adopting an uncorrupted behavior. At the time of striking their collusive deal, the firm and the ex ante monitor anticipate that another monitor may intervene ex post to unveil both the firm's misconduct and evidence of corruptible deals. Bribes can only be transferred when they cannot be detected by an ex post investigation. Smoothing bribes with the ex ante monitor becomes harder and transaction costs of collusion increase for the colluding partners. Some diseconomies of scale in side-contracting appear and can be exploited by splitting ex ante and ex post monitoring.[6]

Because it reduces the social cost of preventing capture, ex post monitoring now takes place more often. As its capture becomes less of a concern under separation, the ex ante monitor might also be called upon more often. This highlights a strong complementarity between ex ante and ex post monitoring. Taking a broader perspective, tougher ex ante regulation and ex post judicial prosecution should come together.

[5]Transaction costs are convex when it is increasingly harder to transfer larger bribes or when such side-transfers can be detected at an increasingly higher rate.

[6]Faure-Grimaud, Laffont and Martimort (2002) also deal with the consequences of ex ante and ex post collusion, but they address different issues.

Practical relevance. Our model is relevant to shed some lights or express concerns on a number of institutional changes that took place in recent years.

Transportation. Transportation offers an illustration of primary interest for our analysis. The investigation of transportation accidents in Canada was, for many years, fully carried out by the Department of Transport. It set the safety standards for the industry, operated elements of the system such as airports and air traffic control, licensed the carriers and the crews, and enforced its own regulations. At the same time, it analyzed the safety failures in the industry in which it had such a pervasive presence. The concern about the independence of the regulator from political pressures grew so heatedly that the government proceeded with the creation of the Canadian Aviation Safety Board, an independent regulatory body with an accident investigation mandate. In the framework of our model, this institutional reform is a move towards separation.

The management of nuclear wastes. In this sector, a broad set of precautionary activities can be implemented at the firm level in order to reduce the likelihood of an accident: care during transportation, employee training programs and radiation competency tests, adoption of best-practices for containment and radiation shielding, integrated safety management... The U.S. Department of Energy (D.O.E.) has inherited the task of cleaning up the radioactive refuse from uranium mines, munitions facilities and other sites around the country. Inside D.O.E., until recently, the Office of Environment, Safety and Health (O.E.S.H.) developed safety policy guidance and provided support to D.O.E. sites, while the Office of Security and Safety Performance Assurance (O.S.S.P.A.) conducted safety oversight. The role of the former office is mainly to ensure that a regulated firm complies with the safety standards whereas the role of the latter office is mainly to investigate when an accident has been reported or discovered. Recently, the D.O.E. has announced the creation of a new office (the Office of Health, Safety and Security) which will undertake enforcement activities previously carried out by both the O.S.H.S. and O.S.S.P.A. This decision is clearly a move towards integration of the tasks of ex ante and the ex post monitoring. Our results below cast doubts on the relevance of such a move.

Literature. The idea that splitting access to privileged information between specialized agencies reduces the costs of capture has previously been investigated by Laffont and Martimort (1998, 1999, thereafter LM). Several important differences exist with the present setting. First, both the ex ante and ex post monitors have access to the same piece of information (even though it is at different points in time due to the specific features of risk regulation), namely the agent's level of safety care, whereas separated agencies get access to different pieces of information in LM. Second, another difference comes from the underlying justifications of the economies of scale that the side-contracting technology exhibits. In LM, building "Chinese walls" between regulators creates asymmetric information in side-contracting. This undermines the efficiency of the side-deals that each regulator reaches with the firm. It is harder to collude with two agencies being partially informed than with a single one having all the relevant information. Here instead, the collusive gains from integration 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.[7] Third, in LM, the monitoring technologies that give informative signals to the firm's monitors are exogenously given whereas we devote some attention to the impact of different institutional choices on the likelihood of each round of investigations.[8]

Other contributions have highlighted the costs and benefits of splitting public bodies. On the benefits side, Kofman and Lawarée (1993) have shown that bringing an uncorruptible monitor may limit the scope for capturing corruptible ones. Our model instead does not assume a priori that this extra monitor is uncorruptible but derives the benefits of separation in a model where both ex ante and ex post supervisors might be captured. Kofman and Lawarée (1996) find that competing agencies may be useful in a yardstick model where they acquire correlated signals. In our model, monitors have instead access to different signals which are conditionally independent and such yardstick mechanisms lose appeal. On the costs side, Shleifer and Vishny (1993) address the question of the optimal number of public officials controlling a given firm. Public officials choose non-cooperatively how much bribes they charge for their services. In equilibrium, excessive bribery occurs with several officials. Although such a result might be convincing in weak institutional environments, the stake for bribery in Shleifer and Vishny (1993) is exogenous. Instead, our model derives this stake from first principles on asymmetric information.

Finally, the literature on the corruption of law enforcers (Becker and Stigler, 1974; Mookherjee and P'ng, 1995; Garoupa, 1997; Polinsky and Shavell, 2001) analyzes the impact of corruption on the likelihood of investigation in various contexts but does not draw, as we do, the consequences of corruption on institutional design. Corruption is there an equilibrium phenomenon. In our context instead, a version of the Collusion-Proofness Principle[9] always holds so that institutions are robust to the threat of capture. The best institutional form minimizes the cost of preventing capture. This institutional perspective is also the focus of Boyer and Porrini (2001, 2004) who compare ex ante regulation and various liability rules enacted ex post. They postulate a priori that the legal system viewed as an ex post monitor is immune to capture, whereas we derive this result from equilibrium behavior. In addition, they analyze separately the costs and benefits of the two systems whereas we model their joint use.[10]

Section 2 presents our theoretical model. Section 3 develops the benchmark without collusion. Section 4 describes our modeling assumptions for capture and studies the impact of collusion on monitoring when either integration or separation is chosen. Section 5 performs a welfare comparison between institutional modes and highlights the possible complementarity between ex ante and ex post monitoring that might arise endogenously

[7]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.

[8]Last, we focus here on moral hazard as the source of the rent that the firm wants to protect by capturing its monitors, whereas LM deal with adverse selection.

[9]See Tirole (1986) for instance.

[10]Earlier contributions, like Wittman (1977), Shavell (1984a, 1984b), Kolstad, Ulen and Johnson (1990), and Mookherjee and P'Ng (1992) compare the use of ex ante regulation and ex post liability rules but impose exogenous constraints on instruments, on information gathering technology, or on both. These institutional issues are instead at the core of our analysis.

under separation. Section 6 briefly concludes. All proofs are relegated to an Appendix.

2 The Model

Consider a firm running a socially risky technology. The probability of an accident affecting third-parties is reduced when this firm exercises safety care. Moral hazard in choosing this variable calls for controlling whether the firm abides to a standard of due care or not.

2.1 Incentives, Information and Control

Moral hazard. Following an accident, third-parties suffer from a damage of social value $D > 0$. The probability of such an accident, $1 - \pi(e)$, is decreasing in the firm's effort e. For simplicity, effort takes only two values, $e \in \{0, 1\}$, so that these probabilities are $1 - \pi_1 < 1 - \pi_0$ (we denote $\Delta\pi = \pi_1 - \pi_0$). Exercising effort $e = 1$ costs ψ to the firm whereas $e = 0$ is costless.[11]

Moral hazard stems both from the non-verifiability of effort and from the conflict between social and private incentives to exercise care. Provided that the damage is large, i.e. $D \geq \frac{\psi}{\Delta\pi}$, efficiency calls for implementing the high level of effort; but the firm prefers to save on the compliance cost.

The firm is protected by limited liability.[12] However, it has some hidden wealth $w > 0$ that can be used for bribery purposes if needed.[13]

Contracts. A regulatory incentive scheme stipulates the firm's payments conditional on its environmental performances, i.e., whether an accident has taken place or not. Because of limited liability, the only relevant payment consists of an incentive reward t following a good environmental performance.[14]

Although we focus on monetary rewards and punishments, a broader interpretation of regulatory incentive payments should be kept in mind so that our model also fits institutional contexts where regulatory rewards are banned. For instance, industrial accidents sometimes come with damages to the fixed capital of the firm or/and to some stakeholders (e.g., workers). Costs may also be indirect and include tightened future regulations, permit refusals by the government, new taxes or future boycotts by environmentally-oriented consumers. Rewards may also involve the firm's implicit reputational gains vis-à-vis customers, potential contracting partners, the government, shareholders and the financial

[11]The cost of effort is non-monetary for simplicity although our modelling could easily be modified to take into account monetary costs without changing our main results.

[12]Firms running risky activities are generally protected by limits on their liability since the consequences of large scale accidents are so staggering that no insurance 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, risky ventures often enter into various activities ("flight-by-night" techniques, spin-offs of subsidiaries, ...) whose goal is to hide seizable assets. Pitchford (2001) and Hiriart and Martimort (2007) analyze the issue of extended liability when ex post legal intervention unveils new funds to compensate victims.

[13]See Section 4.1 below for a description of the capture process.

[14]In full generality, a contract should also stipulate a payment in the event of an accident. However, given the firm's limited liability, this payment would be equal to zero at the optimum.

community.[15]

Monitoring. Monitoring by public bodies might occur either before or/and after an accident. To gather hard evidence on whether the firm complies with standards, on-site random inspections are often used in the regulation of risky activities. Such investigations take place ex ante, i.e. before any accident ever occurs. Instead, ex post audits are run by an accident investigation commission or by the judiciary system following such an accident. Of course, this intervention is only relevant when the ex ante investigation did not take place or failed to release how much effort was undertaken by the firm.

At a cost $C(p_r)$ standing for the cost of resources allocated to ex ante monitoring, an ex ante monitor observes a signal σ_r on the firm's effort level with probability p_r. To focus on interior solutions, $C(\cdot)$ is strictly increasing, sufficiently convex to ensure concavity of the optimization problems below, with $C(0) = 0$, and the Inada conditions $C'(0) = 0$, $C'(1) = +\infty$. The signal $\sigma_r \in \{e, \emptyset\}$ either reveals the firm's effort or is uninformative with respective probabilities $\epsilon \in (0, 1)$ and $1 - \epsilon$. The probability ϵ captures the precision of the signal.

When its misconduct has been detected by the ex ante monitor, the firm is punished with some fines f_r. Those punishments simply consist in suppressing part of the regulatory incentive payment that the firm would have received in case of a good environmental performance, i.e. $f_r \leq t$. Of course, the *Maximal Punishment Principle*[16] applies in our context so that incentives for compliance are fostered when $f_r = t$. This Principle is used throughout to simplify exposition.[17]

Following an accident, and in case it is still unknown whether the firm has abided to the standard, an ex post investigation might occur with probability p_j. The ex post monitor gets a hard information signal $\sigma_j \in \{e, \emptyset\}$ which again perfectly reveals the firm's effort with probability $\epsilon \in (0, 1)$, or is uninformative. On top of detecting effort, this ex post investigation also unveils how much of the hidden funds w are used by the firm for bribery purposes if the ex ante and ex post monitors are two different bodies. To keep symmetry in modelling the ex ante and ex post rounds of investigation, the administrative cost of an ex post investigation is still given by $C(p_j)$.[18] If the ex post monitor figures out that there has been no compliance with the standard of safety care, the firm could a priori be fined. However, remember that the firm's payment is zero following a bad environmental performance so that no fines are actually available for the ex post monitor.

Institutional design. We consider two institutional settings. Under *integration*, the ex ante and ex post monitors are merged into a single entity. Under *separation*, monitors

[15] Lesourd and Schilizzi (2001) discuss the various indirect costs and benefits of environmental risks.

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

[17] For the sake of simplicity, we assume that the firm, when found shirking, cannot change its effort level to adopt the standard. The implicit assumption here is that such an adoption requires major changes in the production technology and these changes take time. In a previous version of this paper, we showed that qualitative conclusions are unchanged if the ex ante monitor could force the firm to adopt immediately the high standard of safety care when $\sigma_r = 0$.

[18] Note that the ex ante and ex post technologies are assumed to be identical to simplify exposition. Most of our results are robust to introducing asymmetries in the costs of monitoring ($C_r \neq C_j$) and differences in the probability of getting an informative signal ($\epsilon_r \neq \epsilon_j$).

are kept apart and behave non-cooperatively. To fix ideas, one may think of the ex ante monitor as a regulator and the ex post one as a judge. Accordingly, in our analysis, regulators and judges differ along two dimensions: the timing of their intervention and the magnitude of the financial penalties they can impose to the firm.[19]

Monitors' wages. If a monitor does not reveal information on the firm's effort, he gets a base-payment normalized at zero. When he reports evidence about the firm's effort, he may receive a positive wage.[20] Let V_r denote the ex ante monitor's wage when he reports the firm's effort after an ex ante investigation. Let similarly V_j be the ex post monitor's wage.[21] These wages should be broadly interpreted. They can stand for the share of the agency budget or resources that can be diverted for private use.[22] Alternatively, they can also be considered as proxies for career concerns.[23]

With probability $p_r\epsilon$, the ex ante intervention succeeds. When it does not and an accident occurs, the ex post monitor is called upon to inspect the firm. When the firm complies with the standard, the expected wage left for monitoring is thus defined as:

$$V(p_r, p_j) = p_r\epsilon V_r + (1 - p_r\epsilon)(1 - \pi_1)p_j\epsilon V_j,$$

where

$$V_r, V_j \geq 0 \tag{1}$$

to ensure participation of the monitors.

[19]Note, however, that our model admits broader and less specific interpretations.

[20]We assume that this wage does not depend on the firm's effort. This is without loss of generality when there is no collusion. This might seem a priori restrictive otherwise. Suppose indeed that the firm's effort, once observed, can be used to condition the monitor's compensation. Even if we do not have yet discussed how collusion between the monitor and the firm takes place, it should be intuitively clear that collusion leads the firm to implement a low effort level. With a wage dependent on the effort level, collusion can be prevented at no cost by offering a high wage $\bar{V}$ to the monitor when he reveals that the firm has shirked. Because the firm's individual incentive constraint is satisfied, this event does not occur along the equilibrium path and raising this wage has no cost for society (see Kessler, 2000). However, when evidence on effort can be manipulated by the monitor, things are different. Suppose that the signal $\sigma_i = e = 1$ $(i = r, j)$ is only partially verifiable and can be manipulated into a report $\hat{\sigma}_i = e = 0$. The scheme above is no longer attractive. Indeed, inducing the monitor to reveal that the firm has actually complied with the standard requires to give him the wage $\bar{V}$. Now the wage $\bar{V}$ is offered on the equilibrium path, which has a social cost. Another justification for ruling out compensations contingent on effort is that they may have a true cost if the firm shirks on effort with some probability on the equilibrium, either because it "trembles" a little bit or because the compliance cost is uncertain.

[21]In full generality, different wages could a priori be offered to the ex post monitor depending on whether an ex ante investigation failed or has not been performed. It turns out that this added degree of generality is not necessary since the optimal collusion-proof wages in those two cases are the same (the proof is available upon request). Therefore, our findings below remain true when this possibility is a priori allowed. Henceforth, our presentation is simplified by assuming directly that those wages are equal.

[22]Niskanen (1971) and Laffont and Tirole (1993).

[23]If this latter perspective is taken, payments to monitors could simply be viewed as the product of the probability of getting a promotion times the private benefit associated to this new job. Whatever the interpretation behind these wages, they remain 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 job.

Social objective. Social welfare incorporates the surplus S generated by the firm's activity, the expected harm on third-parties, the social cost of regulatory transfers and wages and, finally, the administrative costs of monitoring so that, overall, it writes as:

$$W = S - (1 - \pi_1)D - \pi_1 t - V(p_r, p_j) - C(p_r) - C(p_j).$$

Of course, S is large enough so that the firm's activity is valuable, i.e. $W > 0$ at the optimum. Fines for misconduct are not pocketed by the State and do not enter social welfare since the firm is induced to comply with the standard and no such misconduct is detected at equilibrium. The existence of these fines nevertheless helps to relax the firm's incentive constraint and to reduce its liability rent.[24]

Timing. For simplicity, we describe the sequence of events in the case of benevolent monitors. The case of non-benevolent monitors is analyzed in more details in Section 4.1.
• Date 0. The regulatory charter specifies the incentive transfer t, the respective probabilities (p_r, p_j) of ex ante and ex post investigations, fines when misbehavior is detected either ex ante or ex post, and wages for the monitors depending on their reported signals.[25]
• Date 1. The firm exercises an effort $e \in \{0, 1\}$.
• Date 1^+. The ex ante monitor inspects the firm with probability p_r. He learns signal σ_r about the firm's effort. If he detects misconduct ($\sigma_r = e = 0$), he imposes the fine $f_r = t$ that applies if no accident takes place later on.
• Date 2. An accident occurs with probability $1 - \pi(e)$.
• Date 2^+. Following an accident and if nothing has been learned ex ante, the ex post monitor investigates with probability p_j.
• Date 3. Transfers and fines, if any, are paid.

2.2 Incentive compatibility.

To induce the firm to exercise care, the following incentive compatibility constraint must hold:

$$U \equiv \pi_1 t - \psi \geq (1 - p_r\epsilon)\pi_0 t. \tag{2}$$

The l.h.s. of (2) is the firm's expected profit if it complies with the standard since, in that case, the firm is never fined when monitoring (either ex ante or ex post) succeeds. The r.h.s. of (2) is the firm's expected profit if it does not comply with the standard. With probability $p_r\epsilon$, an ex ante inspection occurs and misbehavior is detected. The firm is then fined and loses the incentive reward t. With probability $1 - p_r\epsilon$, ex ante monitoring either does not take place or it takes place and fails. The transfer t is received if the

[24]We could generalize this objective function to take into account redistributive concerns. For instance, the regulatory charter could be more or less aligned with the harmed third-parties depending on whether the risk at stake is global in nature or more local (i.e., whether it affects or not a significant share of the electorate). Also, the regulatory (ex ante) and the judicial (ex post) bureaucracies could receive different weights in the social welfare function. Our modelling choice is made for simplicity, but our results would hold more generally irrespectively of these specifications.

[25]We assume that there is full commitment to the regulatory charter. For the implications of limited commitment in an environment with corruptible auditors, see Strausz (1997) and Khalil and Lawarée (2006).

accident does not occur. If it occurs, ex post monitoring might then be called upon and detect violation with probability $p_j \epsilon$ but, since the firm has no seizable wealth in that state, no fines are imposed.

The incentive constraint (2) yields a lower bound on the incentive payment t. Of course, the optimal regulation aims at minimizing this transfer so that, at the optimum, we have:

$$t^*(p_r, \epsilon) = \frac{\psi}{\Delta\pi + \pi_0 p_r \epsilon}. \tag{3}$$

There are two ways of providing incentives: through monitoring and through the incentive reward in the event of a good environmental performance. Moreover, as shown in the Appendix, the elasticity of the reward with respect to the ex ante audit probability is smaller than one, and decreases when the audit technology becomes less accurate.

Using this expression of the transfer, we may as well obtain the expression of the firm's expected profit as:

$$U = \mathcal{U}(p_r) = \frac{\pi_0(1 - p_r\epsilon)}{\Delta\pi + \pi_0 p_r \epsilon}\psi. \tag{4}$$

The firm's limited liability rent $\mathcal{U}(\cdot)$ is positive, decreasing and convex in p_r. Such a positive profit is a necessary ingredient to have a stake of capture when monitors are not benevolent, as we will show below.

3 Benevolent Monitors

Let us suppose that the ex ante and ex post monitors are both benevolent. There is no need to pay any positive wage to induce these monitors to reveal informative signals on the firm's effort. In such an environment, separation and integration are clearly equivalent.

Ex ante monitoring punishes the firm since it suppresses rewards following a good environmental performance when misconduct has been detected early on. Ex post monitoring is useless because it does not help relaxing the firm's incentive constraint and can only waste administrative resources.

Proposition 1 *With benevolent monitors, the optimal probability of ex ante investigation is strictly positive whereas the probability of ex post investigation is zero:*

$$p_r^* > 0 \text{ and } p_j^* = 0.$$

The optimal incentive payment for the firm is non-negative:

$$t^* > 0.$$

Wages for both rounds of monitoring are zero:

$$V_r^* = V_j^* = 0.$$

4 Preventing Capture

4.1 Collusion Technology

Collusive side-contracts. A firm might bribe its monitors so that they hide information on misconduct. Bribes might take the form of promises for future job opportunities in the private sector 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 already mentioned, the firm has at its disposal some hidden wealth $w > 0$ for bribing its monitors. The firm has all bargaining power in proposing bribes to the monitor(s). A corruptible monitor accepts bribes if he gets more by doing so and being lenient than by remaining honest and releasing misconduct that he may have observed through investigation.

The ex ante monitor's discretion comes from his ability to report having observed $\sigma_r = \emptyset$ when indeed $\sigma_r = e = 0$. The firm avoids then paying fines. This collusive strategy may be attractive if the monitor gets a share of the corresponding gains pocketed by the firm. The ex post monitor could a priori also enjoy similar benefits by hiding ex post evidence of misconduct, i.e., reporting $\sigma_j = \emptyset$ when $\sigma_j = e = 0$.

Monitors only enjoy private benefit $k(\tau) \leq \tau$ when they receive a bribe $\tau \geq 0$. Such frictions are due to the existing transaction costs of side-contracting. The function $k(\cdot)$ is positive increasing, and strictly concave.[26] Convexity of these transaction costs reflects the fact that collusive partners find it increasingly harder at the margin to transfer greater bribes. Colluding partners look for side-deals that minimize the dead-weight loss associated to these transaction costs.

The firm commit to offer the promised bribes to the monitor if he remains lenient. Reciprocally, the regulator commits to stay silent on misconduct.

Collusion-proofness. The possibility that the firm may enter into side-deals with monitors can be viewed as a new dimension of moral hazard.[27] Since side-contracts are non-verifiable by definition and thus cannot be directly banned, the regulatory charter must not only induce a high level of safety care but also prevent the firm from offering collusive side-contracts.

When damages are large enough, restricting attention to collusion-proof regulatory policies is clearly optimal. It is akin to ensuring that the firm does not want to simultaneously deviate by exercising a low level of care and colluding with monitors.

[26] The existence of such transaction costs is a standard assumption in the public choice and regulation literatures (see Congleton, 1984, and Faure-Grimaud and Martimort, 2003, among others). See also Vafai (2002) for another model of collusion in a moral hazard environment with a risk-averse agent based on similar enforceability assumptions.

[27] Laffont (1990) pointed out this analogy between collusion and moral hazard.

4.2 Integration

Suppose first that both monitors are merged into a single entity. The latter's discretion comes from his ability to coordinate reports at the various stages of investigation. When collusion starts ex ante, an enforceable side-contract gives the colluding partners the opportunity to specify bribes following ex post investigation if any is called upon.

Ex post collusion. Let us begin by the simple case of an ex post collusion. If an ex ante investigation fails or is not carried out, the monitor can still intervene ex post. Ex post collusion might occur if the firm is found negligent and the monitor obtains a signal σ_j which is informative on the firm's misconduct.

With such an ex post collusion, a bribe $\tau_j = k^{-1}(V_j)$ is enough to leave the monitor just indifferent between colluding or not ex post. Remember now that the firm's net regulatory transfer following an accident is zero. Colluding secures payoff $w - k^{-1}(V_j)$ whereas not colluding, i.e. paying no bribes, yields only w.

Therefore, ex post collusion does not take place as soon as the following *ex post collusion-proofness constraint* holds:

$$V_j \geq 0. \tag{5}$$

Ex ante collusion. When an ex ante investigation succeeds, the colluding monitor hides information on the low effort undertaken by the firm. The monitor commits not to reveal information if an ex post investigation takes place and also generates hard evidence on the firm's misconduct. In exchange, the firm offers a sequence of bribes $(\tau_r^0, \tau_r^1, \tau_r^2)$. These bribes are respectively offered when an accident does not occur (τ_r^0 with probability π_0), when an accident occurs but ex post investigation fails (τ_r^1 with probability $(1-\pi_0)(1-p_j\epsilon)$), and when an accident occurs and ex post investigation succeeds (τ_r^2 with probability $(1-\pi_0)p_j\epsilon$).

The optimal side-contract $(\tau_r^0, \tau_r^1, \tau_r^2)$ thus solves:

$$(\mathcal{P}^I): \quad \max_{\tau_r^0,\tau_r^1,\tau_r^2 \in [0,w]} \; w + \pi_0(t - \tau_r^0) - (1-\pi_0)(1-p_j\epsilon)\tau_r^1 - (1-\pi_0)p_j\epsilon\tau_r^2$$

subject to

$$\pi_0 k(\tau_r^0) + (1-\pi_0)(1-p_j\epsilon)k(\tau_r^1) + (1-\pi_0)p_j\epsilon k(\tau_r^2) \geq \max\{V_r; (1-\pi_0)p_j\epsilon V_j\}. \tag{6}$$

To collude, the monitor's gain from accepting the side-contract must exceed his wage if he refuses it. Absent collusion, the monitor may either report evidence early or hide it and wait until he is called upon ex post and learns a new signal.

We consider parameter values so that the monitors' wages satisfy:

$$V_r \geq (1-\pi_0)p_j\epsilon V_j. \tag{7}$$

This condition will be checked at the optimum.[28] In that case, the best strategy for the

[28]The monitor's strategy consisting in waiting for some evidence ex post is also a possibility on the equilibrium path, i.e., when the firm exercises an effort. The corresponding constraint, $V_r \geq (1-\pi_1)p_j\epsilon V_j$, holds a fortiori since $\pi_1 > \pi_0$.

monitor when not colluding is to report early the firm's misconduct.

Because transaction costs are convex, smoothing bribes and offering a flat bribe τ_r^I under all contingencies reduces the dead-weight loss of side-contracting. Given that the firm has all bargaining power when designing side-contracts, it optimally offers a bribe that makes the monitor just indifferent between colluding or not:

$$\tau_r^0 = \tau_r^1 = \tau_r^2 \equiv \tau_r^I = k^{-1}(V_r).$$

Such a bribe is feasible when the firm has enough hidden wealth available, i.e., $w > \tau_r^I$ or, equivalently:

$$V_r < k(w). \tag{8}$$

With such a flat bribe, the firm's gain from ex ante collusion is thus $w + \pi_0 t - k^{-1}(V_r)$. Instead, if the firm does not offer the bribe τ_r^I and misconduct is revealed, the firm keeps w. A regulatory scheme is *ex ante collusion-proof* when the firm prefers not to collude, i.e., when the wage V_r satisfies the following *ex ante collusion-proofness constraint*:

$$V_r \geq k(\pi_0 t). \tag{9}$$

Incentive compatibility and collusion-proofness. Let us now describe the firm's incentive constraint when collusion matters. As already stressed, the regulatory charter must not only induce the firm to comply with the standard but also not to collude with its monitor, be it either ex ante or ex post. The following *generalized incentive constraint* aggregates all possible deviations available to the firm:

$$U \geq p_r \epsilon \max\left\{0; \pi_0 t - k^{-1}(V_r)\right\} + (1 - p_r \epsilon)\left(\pi_0 t + (1 - \pi_0) p_j \epsilon \max\left\{0; -k^{-1}(V_j)\right\}\right). \tag{10}$$

Clearly, in the state where an accident takes place and ex post investigation unveils misbehavior, paying a bribe is useless since the firm has nothing to save.

Response to the threat of capture. Since giving up some extra rents to the monitor is socially costly, the collusion-proofness constraints (5) and (9) are both binding at the optimum. Avoiding capture requires to give up the following monitoring wages:

$$V_r^I = k(\pi_0 t) \quad \text{and} \quad V_j^I = 0. \tag{11}$$

With these wages, the firm's incentive constraint remains the same with or without collusion, i.e., (10) coincides with (4). Hence, for fixed investigation probabilities, the firm receives the same liability rent $\mathcal{U}(p_r)$ and the same transfer $t^*(p_r, \epsilon)$ following a good environmental performance as when monitors are benevolent. Payments and rent are thus respectively given by (3) and (4).

Investigation probabilities. Turning now to the optimal investigation probabilities, we get:

Proposition 2 *The probabilities of investigation under integration are lower than with benevolent monitors when collusion is a concern:*

$$p_r^I \leq p_r^*, \text{ and } p_j^I = 0. \tag{12}$$

Considering the probability of ex ante investigation, several opposite effects are simultaneously at play. For a given stake of collusion between the merged entity and the firm, reducing this probability helps reducing the expected wage needed to ensure ex ante collusion-proofness. as with benevolent monitors, reducing this probability increases the incentive reward $t^*(p_r, \epsilon)$ and makes the incentive constraint (2) more demanding. However, with corruptible monitors, the stake of collusion is increased making the collusion-proofness constraint (9) is more difficult to satisfy too. The first of these effects always dominates since the elasticity of the reward with respect to the ex ante audit probability is smaller than one, making the impact of p_r on the stake of collusion less important. Overall, this pushes towards less ex ante investigation.

4.3 Separation

Consider now the case where each round of investigation is run by a different monitor. The key difference with the case of integration is that, when deciding whether to collude or not with the ex ante monitor, the firm also anticipates the issue of side-contracting with the ex post monitor.

Ex post collusion. Absent any ex ante investigation, or when such investigation has failed, the same logic as under integration applies and the corresponding ex post collusion-proofness constraint is again given by (5).

Ex ante collusion. A side-contract for the ex ante monitor stipulates a priori some non-negative bribes $(\tau_r^0, \tau_r^1, \tau_r^2)$ respectively when an accident does not occur and when an accident does occur but ex post investigation either fails or succeeds.

Consider the last possibility. Through his own investigation, the ex post monitor not only observes the firm's effort but also the bribe τ_r^2 exchanged if any, detecting thereby possible collusion between the ex ante monitor and the firm. Anticipating that the ex post monitor is uncorruptible in equilibrium, the firm and the ex ante monitor should strike their best collusive deal knowing that the ex post monitor is committed to report information on their misbehavior when such disobedience is detected. In particular, we assume that the regulator would lose all collusive benefits (may be under the form of reputational stigma or financial penalties) following such detection. From the firm's viewpoint, transferring bribe to that ex ante monitor in the event where the ex post monitor investigates is thus just a pure loss. It does not raise the ex ante monitor's expected benefit from colluding and only reduces the firm's expected payoff. Hence, the firm finds it optimal not to bribe the ex ante monitor in case an ex post investigation succeeds.

Therefore, the optimal side-contract (τ_r^0, τ_r^1) offered to the ex ante monitor when he observes $\sigma_r = 0$ and pretends that $\sigma_r = \emptyset$ must solve:

$$(\mathcal{P}^S): \quad \max_{\tau_r^0, \tau_r^1 \in [0,w]} \; w + \pi_0(t - \tau_r^0) - (1-\pi_0)(1-p_j\epsilon)\tau_r^1$$

$$\text{subject to } \pi_0 k(\tau_r^0) + (1-\pi_0)(1-p_j\epsilon)k(\tau_r^1) \geq V_r. \tag{13}$$

Separation reduces the possibilities for smoothing bribes with respect to integration. Bribes with the ex ante monitor are now exchanged in two states of nature instead of three. This captures the intuition that, under separation, there are less points of contact between the firm and its ex ante monitor.

Nevertheless, the dead-weight loss of side-contracting is still minimized with a flat bribe over contingencies where such a collusion is feasible:

$$\tau_r^0 = \tau_r^1 \equiv \tau_r^S = k^{-1}\left(\frac{V_r}{\alpha}\right)$$

where $\alpha = \pi_0 + (1-\pi_0)(1-p_j\epsilon)$ is the probability that an ex post investigation fails given a successful first round of investigation.

The firm's net benefit from ex ante collusion is thus $\pi_0 t - \alpha\tau_r^S$. The ex ante collusion-proofness constraint can thus be written as:

$$V_r \geq \alpha k\left(\frac{\pi_0 t}{\alpha}\right). \tag{14}$$

Response to the threat of capture. The overall cost of preventing capture is again obtained when the expected wage left to monitors is minimized, which implies that (5) and (14) are both binding:

$$V_r^S = \alpha k\left(\frac{\pi_0 t}{\alpha}\right) \text{ and } V_j^S = 0. \tag{15}$$

Proceeding as before, the generalized incentive constraint that induces the firm to exercise effort and not to collude with both the ex ante and ex post monitors can still be written as (10). It again boils down to the standard incentive constraint (4) when (5) and (14) are both binding. The optimal incentive transfer is unchanged and still given by (3). Hence, V_r^S becomes a function of (p_r, p_j) through the direct dependence of $t^*(p_r, \epsilon)$ on p_r and the dependence of α on p_j.

5 Welfare Comparison

Only the wages left for ex ante monitoring differ in both scenarios. For some fixed investigation probabilities (p_r, p_j), the welfare difference between separation and integration is just the difference in those wages:

$$\Delta W(p_r, p_j) = p_r\epsilon\left\{V_r^I(p_r) - V_r^S(p_r, p_j)\right\} = p_r\epsilon\left\{k\left(\pi_0 t^*(p_r,\epsilon)\right) - \alpha k\left(\frac{\pi_0 t^*(p_r,\epsilon)}{\alpha}\right)\right\}.$$

Since $\alpha < 1$, $t^*(p_r, \epsilon) > 0$ and $k(\cdot)$ is strictly concave, $\Delta W > 0$ and we can provide the main result of this paper:

Theorem 1 *Under the threat of capture, and for any probabilities of investigation* (p_r, p_j)*, separation improves welfare:*

$$\Delta W(p_r, p_j) > 0.$$

Transaction costs of side-contracting are greater under separation than under integration. The mere fact that the ex ante monitor and the firm cannot exchange bribes in all the states of nature makes it more difficult to collude ex ante.

The convexity of transaction costs is key for this result. Had transaction costs been linear, non-benevolent monitors would not care about smoothing bribes and separation would be equivalent to integration. Indeed, let us compare the "potential" bribe that the firm provides to the ex ante monitor under separation and integration. It is straightforward to see that:

$$\tau_r^I = \alpha \tau_r^S. \tag{16}$$

Therefore, the ex ante monitor under separation earns the same expected bribe than the ex ante monitor under integration. Indeed, in both cases, the firm wants to secure the liability rent $\pi_0 t^*(p_r, \epsilon)$. Comparing separation with integration, having higher bribes but less often is not costly when $k(\cdot)$ is linear. However, bribes have more variance under separation. The strict convexity of transaction costs ensures that separation increases transaction costs and improves welfare. Intuitively, the same expected amount of bribes has to be distributed under integration and separation. But, since there are fewer points of contact between the colluding partners under separation, the size of the bribe in each state of nature is raised and this increases the deadweight loss of side-contracting.

Investigation probabilities. To give some preliminary insights on how the optimal probabilities of investigation under separation and integration compare, consider the simple case where $k(x)$ is quadratic, namely, $k(\tau) = \kappa\tau - \frac{\mu}{2}\tau^2$ for some $\kappa \in [0, 1]$ and $\mu \geq 0$ such that $k(\cdot)$ is increasing on the relevant range. The welfare gain of separation can finally be written as:

$$\Delta W(p_r, p_j) = \frac{\mu \pi_0^2 (1 - \pi_0)(t^*(p_r, \epsilon))^2}{2\alpha} p_r p_j \epsilon^2 > 0. \tag{17}$$

Those gains increase with the probability of an ex ante investigation since one can save on monitoring wages by splitting monitoring tasks under separation. However, when an ex post investigation is more likely, the transaction costs of side-contracting increase because the possibility of smoothing bribes under separation only occurs under contingencies which are relatively less likely. Bringing the ex post monitor in more often becomes thus more attractive. Denoting by (p_r^S, p_j^S) the optimal investigation probabilities under separation, we finally get:

Proposition 3 *Assume that* $k(\cdot)$ *is quadratic. Under separation, there is more ex post investigation than under integration and more ex ante investigation if* ϵ *is small enough:*

$$p_j^S > 0 \text{ and } p_r^S > p_r^I \Leftrightarrow \Delta\pi > \pi_0 p_r^S \epsilon.$$

From (17), we immediately deduce that the welfare gain from a marginal increase of the ex post investigation under separation is positive, i.e. $\frac{\partial \Delta W}{\partial p_j} > 0$. Instead, increasing p_r decreases the stake of collusion $\pi_0 t^*(p_r, \epsilon)$ since this reduces the limited liability rent. However, increasing p_r also raises the probability of ex ante collusion, but it is less problematic under separation than under integration. The second of these effects dominates, and $\frac{\partial \Delta W}{\partial p_r} > 0$, when ϵ is small enough since the elasticity of $t^*(p_r, \epsilon)$ with respect to p_r is then small.

A recurrent question concerning the use of regulators or judges is whether they are substitutes or complements. Our model sheds some light on this issue. The formula (17) shows under which conditions those two bodies are actually complements in improving welfare. Indeed, when ϵ is small enough, it becomes more valuable to use ex ante investigation under separation because the stake of collusion is reduced. At the same time, ex post intervention is always more attractive. By raising at the margin the probability of bringing the judge in ex post, ex ante collusion with the regulator becomes harder, making regulation more attractive.

When monitoring is not too efficient, either because the optimal ex ante audit probability is small or because the accuracy of the signal is weak, the condition $\Delta\pi > \pi_0 p_r^S \epsilon$ holds and ex ante and ex post interventions are complements.

It is striking to show that, even though the judge himself may be corruptible, an ex post investigation is now valuable contrary to a collusion-free environment. The threat of wasting resources bribing a judge forces the firm and the regulator to collude in less efficient ways under separation which is socially beneficial. There is an interesting division of tasks between public bodies: ex ante regulation helps relaxing the firm's incentive constraint whereas ex post judicial investigation helps relaxing the possible collusion between the firm and its regulator.

Robustness. So far, we have assumed that the ex ante monitor and the firm, at the time of striking their deals, anticipate that the ex post investigator will not collude. Reciprocally, the ex post monitor also anticipates that the ex ante monitor is not corrupted. These simple behavioral assumptions, where both agencies choose ex ante whether to collude or not, helped us to get clear results on the benefits of separation.

Let us now turn to the more intricate hypothesis where the ex ante monitor and the firm design their deal anticipating its impact on the ex post monitor's incentives to collude or not. Such an anticipatory behavior corresponds to a setting where the ex post monitor has a limited ability to commit to a behavior against the firm and waits for valuable opportunities to collude if any.

Based on our previous findings, it is relatively straightforward to compute the firm's net gain of buying the ex post monitor's services with a bribe $k^{-1}(V_j)$ if it also plans to collude with the ex ante monitor, giving the latter a flat bribe $k^{-1}(V_r)$ in all states of nature. This gain writes as:

$$w + \pi_0 t - k^{-1}(V_r) - (1-\alpha)k^{-1}(V_j).$$

Instead, when not buying the ex post monitor's lenient behavior, the firm can only exchange with the ex ante monitor a flat bribe $k^{-1}\left(\frac{V_r}{\alpha}\right)$ in the two remaining states of nature. The firm gets thereby:

$$w + \pi_0 t - \alpha k^{-1}\left(\frac{V_r}{\alpha}\right).$$

Clearly, the firm does not find attractive to collude with the ex post monitor when the second payoff dominates. This yields the following expression of the ex post collusion-proofness constraint:

$$V_j \geq k\left(\frac{1}{1-\alpha}\left(\alpha k^{-1}\left(\frac{V_r}{\alpha}\right) - k^{-1}(V_r)\right)\right). \tag{18}$$

Together with the ex ante collusion-proofness constraint (14), this defines the set of wages ensuring no collusion either ex ante or ex post.

It can readily be seen that the right-hand side of (18) is strictly positive when (14) is binding. This means that with such anticipatory behavior, the ex post monitor must now receive a positive wage. The benefits of lower payments to the ex ante monitor must be weighted against the cost of higher payments for the ex post monitor. The first effect dominates when $p_r\epsilon$ is large enough, in which case an ex post investigation is unlikely.

As an example, assume that transaction costs of side-contracting are quadratic, $k(\tau) = \tau - 1/2\tau^2$, and that bribes are small enough.[29] Then, $k^{-1}(v)$ can be approximated (up to terms of order more than 2) by $v + 1/2v^2$. In equilibrium, the ex ante monitor and the firm do not collude (while anticipating that the ex post monitor is not corrupted) if the ex ante collusion-proofness (14) is satisfied. The ex post collusion-proofness constraint (18) becomes: $V_j \geq V_r^2/(2\alpha)$. Simple manipulations show that:

$$\Delta W(p_r, p_j) = \frac{\pi_0^2(t^*(p_r,\epsilon))^2}{2\alpha}[(1-\alpha)p_r - (1-p_r\epsilon)(1-\pi_1)p_j]\epsilon.$$

When p_r is large enough, $\Delta W(p_r, p_j) > 0$ and separation dominates integration, which confirms our initial intuition.

6 Conclusion

This paper has stressed the benefits of splitting ex ante and ex post monitoring of environmentally risky ventures in a moral hazard environment. Having an independent ex post monitor intervening only upon an accident makes it more difficult for the firm to collude with the ex ante monitor whose control is more routinized. Regulatory capture is less of a concern under separation and this institutional choice improves social welfare.

Although our model generates some value for separation to improve the fight against capture, it is worth stressing other potential benefits of separation that could be added in a more complete model. First, separation may help to generate evidence because it allows to cross-check the monitors' announcements.[30] Second, duplication of expertise between

[29] This arises for instance when ψ is small so that $\pi_0 t^*(p_r,\epsilon)$ is also small.
[30] For a similar argument, see Laffont (2000).

ex ante and ex post monitors may facilitate specialization in gathering information on different dimensions of the firm's activities. The ex ante regulators are certainly more prone to gather technical information whereas ex post judges would instead focus on testimonies by private parties. Investigating both the incentives for specialization and its consequences for institutional design would certainly be a valuable extension to our analysis.

From a theoretical viewpoint, our approach for modelling collusive behavior between the private sector and public bodies differs significantly from other studies of corruption in the regulation or law enforcement literature which have instead stressed the equilibrium nature of corruption.[31] In our paper, collusion is prevented by an adequate design of incentive rewards and comparison between institutions amounts to looking for the organizational form that minimizes the cost of preventing collusion. It would be interesting to investigate environments where collusion would be an equilibrium phenomenon. This could be done by introducing some non-observable heterogeneity among monitors, for instance, in terms of their willingness to collude or in terms of their psychological costs of being caught lying.[32] How institutions change the equilibrium level of corruption is then an important topic that would be worth investigating.

Our analysis provides a number of testable implications. The first one is that splitting ex ante and ex post investigations should increase the likelihood to rely on either of those arms and, by the same token, their administrative costs. The flip side of separation is thus a possible increase in regulatory budgets. Since one should expect norms of collusive behavior to become stronger over time, the second implication of our analysis is that the benefits of separation are more likely to occur for mature fields where the nature of the risk at stake and the active players are already well defined so that collusion is easily enforceable. We leave for future research the investigation of those testable implications.

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

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

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Appendix

Proof of Proposition 1. We first compute the agency cost necessary to implement the high level of safety care given the investigation probabilities. Second, we determine optimal probabilities taking into account agency and administrative costs.

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

$$\mathcal{C}^*(p_r, p_j) \equiv \min_{\{U,V_r,V_j\}} U + V(p_r, p_j) + C(p_r) + C(p_j) \text{ subject to (1) and (4).}$$

When monitors are benevolent and report truthfully any information they may gather on the firm's effort, wages are optimally set at zero ((1) is binding) so that $V(p_r, p_j) = 0$. The optimal probabilities of investigation $\left(p_r^*, p_j^*\right)$ are given by:

$$\left(p_r^*, p_j^*\right) = \arg \min_{\{p_r,p_j\}} \mathcal{C}^*(p_r, p_j) = \mathcal{U}(p_r, p_j) + C(p_r) + C(p_j).$$

First-order necessary (and sufficient given strict convexity of the objective function) conditions give us:

$$C'(p_r^*) = \frac{\pi_1 \pi_0 \psi \epsilon}{(\Delta\pi + \pi_0 p_r^* \epsilon)^2} > 0 \text{ and } C'(p_j^*) = 0. \tag{19}$$

The expression for $t^*(p_r, \epsilon)$ is given by (3) with the optimal probability above.

Proof of Proposition 2. Under integration, and for some fixed probabilities of investigation, the optimal regulatory charter solves:

$$\mathcal{C}^I(p_r, p_j) \equiv \min_{\{t,V_r,V_j\}} U + V(p_r, p_j) + C(p_r) + C(p_j) \text{ subject to (5), (9) and (10).}$$

This immediately yields the expressions of wages for monitoring in (11). Taking into account those wages and the expression of the firm's liability rent, the optimal investigation probabilities solve:

$$\left(p_r^I, p_j^I\right) = \arg \min_{\{p_r,p_j\}} \mathcal{C}^I(p_r, p_j) \equiv \mathcal{C}^*(p_r, p_j) + p_r \epsilon k \left(\pi_0 t^*(p_r, \epsilon)\right).$$

The derivatives of this objective function w.r.t p_r and p_j are respectively given by:

$$\frac{\partial \mathcal{C}^I(p_r, p_j)}{\partial p_r} = \frac{\partial \mathcal{C}^*(p_r, p_j)}{\partial p_r} + \epsilon \left(k\left(\pi_0 t^*(p_r, \epsilon)\right) + \pi_0 p_r \frac{\partial t^*(p_r, \epsilon)}{\partial p_r} k'\left(\pi_0 t^*(p_r, \epsilon)\right) \right), \tag{20}$$

$$\frac{\partial \mathcal{C}^I(p_r, p_j)}{\partial p_j} = \frac{\partial \mathcal{C}^*(p_r, p_j)}{\partial p_j} = C'(p_j). \tag{21}$$

Note that

$$\eta_r \equiv -\frac{p_r}{t^*(p_r, \epsilon)} \frac{\partial t^*(p_r, \epsilon)}{\partial p_r} = \frac{\pi_0 p_r \epsilon}{\Delta\pi + \pi_0 p_r \epsilon} < 1.$$

Therefore, we get

$$\begin{aligned}&k\left(\pi_0 t^*(p_r,\epsilon)\right)+\pi_0 p_r\frac{\partial t^*(p_r,\epsilon)}{\partial p_r}k'\left(\pi_0 t^*(p_r,\epsilon)\right)\\&=k\left(\pi_0 t^*(p_r,\epsilon)\right)-\eta_r\pi_0 t^*(p_r,\epsilon)k'\left(\pi_0 t^*(p_r,\epsilon)\right)\\&>k\left(\pi_0 t^*(p_r,\epsilon)\right)-\pi_0 t^*(p_r,\epsilon)k'\left(\pi_0 t^*(p_r,\epsilon)\right)>0,\end{aligned}$$

where the last inequality follows from the concavity of $k(\cdot)$. This implies $\frac{\partial \mathcal{C}^I}{\partial p_r}(p_r,p_j) > \frac{\partial \mathcal{C}^*}{\partial p_r}(p_r,p_j)$ and thus $p_r^I < p_r^*$. Also, we immediately get $p_j^I = 0$. ■

Proof of Proposition 3. Under separation, and for some fixed probabilities of investigation, the optimal regulatory charter solves:

$$\mathcal{C}^S(p_r,p_j)\equiv\min_{\{t,V_r,V_j\}} U+V(p_r,p_j)+C(p_r)+C(p_j) \text{ subject to (5), (10) and (14).}$$

This immediately yields the expressions of wages for monitoring in (15). Taking into account those wages and the expression of the firm's liability rent, the optimal investigation probabilities solve:

$$\begin{aligned}\left(p_r^S,p_j^S\right)&=\arg\min_{\{p_r,p_j\}}\mathcal{C}^S(p_r,p_j)\equiv\mathcal{C}^I(p_r,p_j)+p_r\epsilon\left[\alpha k\left(\frac{\pi_0 t^*(p_r,\epsilon)}{\alpha}\right)-k(\pi_0 t^*(p_r,\epsilon))\right]\\&\equiv\mathcal{C}^I(p_r,p_j)-\frac{(1-\alpha)\mu(\pi_0 t^*(p_r,\epsilon))^2}{2\alpha}p_r\epsilon.\end{aligned}$$

From this, we compute:

$$\frac{\partial \mathcal{C}^S(p_r,p_j)}{\partial p_r}=\frac{\partial \mathcal{C}^I(p_r,p_j)}{\partial p_r}-\frac{\mu\pi_0^2(1-\pi_0)\psi^2(\Delta\pi-\pi_0 p_r\epsilon)}{2\alpha(\Delta\pi+\pi_0 p_r\epsilon)^3}p_j\epsilon^2$$

and thus $p_r^S > p_r^I \Leftrightarrow \Delta\pi > \pi_0 p_r^S\epsilon$. Also, we get:

$$\frac{\partial \mathcal{C}^S(p_r,p_j)}{\partial p_j}=C'(p_j)-\frac{\mu\pi_0^2(1-\pi_0)\psi^2}{2\alpha^2(\Delta\pi+\pi_0 p_r\epsilon)^2}p_r\epsilon^2.$$

This yields also $p_j^S > 0$. ■