

# The Regulator and the Judge: The Optimal Mix in The Control of Environmental Risk\*

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## Abstract

A firm engaged in activities which are environmentally risky has private information both on its choice of safety care and on the level of its assets.

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## 1 Introduction

Whether tort liability or regulation is best suited to cope with accidents is one of the lasting discussions in the law and economics literature. In the field of environmental risk regulation, defining the optimal policy-mix between regulation and liability is an issue of a tantamount importance if one wants that private actors fully internalize the impacts of their decisions on third-parties and the environment. In a world plagued with various informational asymmetries and much uncertainty on the outcomes of production processes that put the environment at risk, relying on either the regulator or the judge are two corrective policies which are well-known to differ both in terms

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of their effectiveness from an incentive viewpoint but also in terms of their respective administrative costs.

Regulation of environmentally risky ventures requires indeed to enforce standards of care that should be undertaken by private actors and to check compliance. Regulation usually takes the form of routine procedures which take place *ex ante*, i.e. before any harm ever occurs.<sup>1</sup> Tort liability instead is used *ex post* through law suits which are only triggered following an accident. These procedures have a significant incentive role by forcing responsible parties to pay for damages. A proper compensation of the victims or the cleanup of contaminated sites in the case of a disaster require that injuring parties disgorge cash. The judge has a stake in discovering the financial capacity of injuring parties, whereas much of the structure and organization of risky industries precisely aims at escaping those liability payments.<sup>2</sup>

This brief description of the two kinds of policies available to control environmental risk already stresses a fundamental difference. Whereas risk regulators have expertise to check whether firms shirk on care or not, judges have instead developed the legal expertise to unveil the true assets value of these firms once held liable.<sup>3</sup> Those two distinct dimensions of enforcement deal in fact with two incentive problems of a quite different nature. First, it is indeed hard to ascertain whether a firm follows a standard of due care or not and some (random) regulatory inspection is needed: a moral hazard problem. Second, it is often difficult to assess the true value of the firm's assets: an adverse selection problem. The judge's intervention helps unveiling this value by piercing the corporate veil behind which environmentally risky firms may hide.

In this paper, we take as given this functional separation of tasks between the regulator and the judge and determine the optimal policy mix. Both the judge and the regulator participate to the enforcement of corrective policies and may impose either explicit fines or implicit punishments (such as reputational losses) on firms when they are caught shirking on care or hiding assets. The judiciary and the regulatory branches both contribute to the design of the overall package of incentives and thus, they both improve welfare.

However, the exact interaction between these tasks is far from being obvious. On the one hand, the threat of having the true value of the firm's assets being revealed in a lawsuit might help the regulator to set up the right amount of fines. On the other hand, the threat of being caught shirking by a regulator increases the firm's incentives to exert care. This reduces the likelihood of an accident and thus of an *ex post* investigation of the firm's assets by the judge.

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<sup>1</sup>For instance, the *French Directions Régionales de l'Industrie de la Recherche et de l'Environnement* are agencies authorizing agricultural or industrial plants –among which 1148 present a risk a major accident involving hazardous substances– presenting a risk of pollution or nuisance to exert their activity, and are in charge for checking whether firms follow procedures and guidelines for the risk management. In the U.S., such agencies as Occupational Safety and Health Administration (OSHA) or EPA regularly investigate care.

<sup>2</sup>See Ringleb and Wiggins (1990) for an empirical analysis of these strategies.

<sup>3</sup>The U.S. 1980 Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) gives an example of the legal arsenal developed by judges to find out the money needed to restore contaminated sites. Under CERCLA, any owner or operator of an environmentally risky venture may be found liable for the potentiel losses generated by the firm's activity if the latter is itself judgment-proof, i.e., if its assets cannot cover the cleanup costs of the contaminated site.

This paper analyzes this two-way interaction between regulatory and legal interventions and describes the optimal package for enforcement policies in various legal environments. We investigate three different scenarios of increasing complexity.

In the first scenario, the judge only checks the value of the firm's assets if the regulator did not perform any inspection himself. This setting serves as a useful benchmark for the rest of our investigation. When regulatory enforcement is rather efficient, the standard of due care is easily enforced. It is then relatively more tempting for the firm to hide its assets than to shirk on care since the judge is quite unlikely to intervene. Decreasing the probability of regulatory enforcement and, at the same time, increasing the resources that the judge devotes to unveil assets facilitates truth-telling. This increases the possible fines that may be paid if an accident occurs and, by the same token, reduces the regulatory rewards when no accident occurs.<sup>4</sup> The regulator and the judge are then substitutes.

Quite paradoxically, this is precisely when solving the moral hazard problem (i.e., enforcing the efficient level of care) becomes easier than the adverse selection problem (i.e., finding out the value of the firm's assets) is harder. The optimal policy-mix under this first regime calls for trading off the benefits of *ex post* and *ex ante* enforcements.

The scope for this substitutability between the regulator and the judge is then challenged in more complex environments. The judge intervenes now whether regulatory enforcement has taken place or not.

In the second scenario, the judge commits resources to unveil assets whatever the regulatory outcome, i.e., whether a regulatory inspection has taken place or not. Under this second regime, both the regulator and the judge are useful in giving incentives to the firm but they no longer interact.

Finally, in the last scenario, the judge may fine tune the amount of resources devoted to unveil the firm's assets to the regulatory outcome. This scenario reveals a complex web of interaction between the regulator and the judge. When the technology of *ex ante* audit is efficient, then the likelihood that the firm may encounter both the regulator and the judge is relatively high. When this technology is instead inefficient, then there is a high probability that the firm may just encounter the judge.

Let us now review the relevant literature. Starting with Wittman (1977) and White and Wittman (1983), an earlier trend of the literature has analyzed the performances of *ad hoc* regulatory and liability mechanisms under either uncertainty or imperfect information, sometimes arguing strongly in favor of liability rules.<sup>5</sup> Shavell (1984a) discussed and compared the incentive properties of the two policies in a moral hazard environment with also uncertainty on the level of harm.<sup>6</sup> He showed that liability undermines the level of care for potentially judgment-proof parties or when injuring parties might escape litigation, whereas a regulatory standard performs well when uncertainty on the harm level is sufficiently small. This comparison is somewhat rudimentary both in terms of the incentive mechanisms

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<sup>4</sup>As we will discuss below, these rewards may either be explicit or implicit, taking the form of reputational gains for instance.

<sup>5</sup>See also Weitzman (1974) and Yohe (1978).

<sup>6</sup>See also Shavell (1984b) for some informal arguments.

allowed and because it assumes away the cost of enforcement policies. Still in a framework with ad hoc mechanisms, Kolstad, Ulen and Johnson (1990) did not see liability and regulation necessarily as substitutes and argued that some complementarity may appear between both instruments.<sup>7</sup> In the present paper, we also start as these latter works from the presumption that an ex post investigation by the judge certainly generates information<sup>8</sup> whereas regulation helps in enforcing a standard of care. Working in a model with optimal incentive mechanisms and endogenizing the probability of investigation by either branch, we put on the front line of the analysis the institutional details of the legal environment and the nature of the enforcement costs showing that those are key elements to delineate the optimal policy-mix.

Boyer and Porrini (2001 and 2004) argued as we do here that regulation and liability (more precisely extended liability towards principal vertically linked with a judgment-proof firm) both involve some kind of monitoring activities. They stress an interesting trade-off coming from the comparison between the cost of a captured regulation and the cost of having the firm's principals (be they lenders or parent firms) with an objective different from the social objective in a context of extended liability. Contrary to these papers, we do not consider regulation and liability as two mutually exclusive alternatives but we are interested in their optimal mix. Also, we do not address the political economy issues and most specifically the reasons why the regulator and the judge should be split as two different entities, a question that we tackle in a companion paper (Hiriart, Martimort and Pouyet (2005)).<sup>9</sup>

Finally, Mookherjee and P'Ng (1992) also stressed the difference between ex ante and ex post monitoring<sup>10</sup> but, following Shavell (1984a), addressed other sets of issues related to the fact that ex post, the size of a damage is better known than ex ante.

Section 2 presents our model. In Section 3, we provide some useful benchmarks where the overall investigation capacity of the State is limited. In particular, the judge never intervenes. This stresses the difficulty in building a regulatory mechanism able to screen firms according to their assets values without bringing the judge in. In Section 4, we introduce the judge into the picture and stress its interaction with the regulator. Section 5 provides some extensions and discusses further the allocation of tasks between the regulator and the judge. Section 6 concludes. Proofs are relegated to an Appendix.

## 2 The Model

We consider a relationship between a firm, a regulator and a judge. The cornerstone of our analysis relies on the following ingredients: the environmental risk created

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<sup>7</sup>In Hiriart, Martimort and Pouyet (2004), we showed that a joint use of regulation and liability helps implementing the first-best level of care when there are no a priori restriction on incentive mechanisms.

<sup>8</sup>Not on harm as in Shavell (1984a) but on the level of the firm's assets, an assumption which is more in lines with legal provisions in CERCLA in the U.S..

<sup>9</sup>Our point there is to show that splitting ex ante and ex post investigations is the best way to prevent capture of both arms of control.

<sup>10</sup>To make the distinction easier, these authors call the second kind of monitoring 'investigation'. We won't make such semantic difference.

by the firm's activities; the presence of asymmetric information in the form of both adverse selection on the value of the firm's assets and moral hazard on safety care; the ex ante intervention of the regulator and ex post intervention of the judge. We now describe these elements.

## 2.1 The Firm

By its mere activity, a firm may provoke an environmental damage of size  $D$  which may harm third-parties. One may think of these damages as oil spills by oil-carrying vessels during transportation or as chemical leakages from underground storage tanks.

The probability of an accident  $\pi(\cdot)$  depends on a firm-specific effort  $e$  towards safety care, which, for convenience, is assumed to be binary:  $e \in \{0, 1\}$ . When the firm exerts the high level of precautionary effort (i.e.,  $e = 1$ ) the probability of an accident is  $1 - \pi_1$ . By contrast, if the firm undertakes the low effort level (i.e.,  $e = 0$ ) then the probability of a damage becomes  $1 - \pi_0 > 1 - \pi_1$ , with  $\Delta\pi \equiv \pi_1 - \pi_0 > 0$ . To exert effort  $e = 1$  (respectively  $e = 0$ ), the firm must bear a positive non-monetary cost  $\psi$  (respectively 0).<sup>11</sup> The privately observed precautionary effort is therefore a moral hazard variable.

To focus on the interesting cases, we shall make the following assumption.

**Assumption 1.** *It is always socially desirable that the firm exerts the high level of precautionary effort.*

This assumption is innocuous since it always holds at equilibrium provided that the damage  $D$  in the event of an accident is sufficiently large to offset the costs of inducing such a high level of precautionary effort.

Let us now consider another crucial feature of our model, namely the firm's assets value. The firm owns assets whose total value is denoted by  $\theta \in \Theta = \{\underline{\theta}, \bar{\theta}\}$ , with  $\Delta\theta \equiv \bar{\theta} - \underline{\theta} > 0$ . Let  $\nu = \text{Prob}(\theta = \bar{\theta}) = 1 - \text{Prob}(\theta = \underline{\theta})$ . The firm is privately informed on  $\theta$ , an adverse selection parameter. As regards the possibility for the firm to conceal the value of its assets, we make the following assumption.

**Assumption 2.** *Overstatement of the assets' value by the firm is not possible.*

Differently stated, claiming to be of type  $\hat{\theta}$  requires the firm to gather hard evidences that the value of its assets is at least as high as  $\hat{\theta}$ .<sup>12</sup>

## 2.2 Ex Ante and Ex Post Interventions

We consider now the 'control' of the firm's activities. This control has to be considered in a broad sense. It includes the many different ways in which the firm's

<sup>11</sup>Our model could easily be generalized to the case of a monetary cost of maintaining safety care at the cost of a slighter more complex modeling.

<sup>12</sup>This is a standard assumption in the literature on contracting with financially constrained agent. See Gale and Hellwig (1985), Townsend (1979), and Lewis and Sappington (2000 and 2001).

decisions are affected and regulated by the State. The following distinction is useful. Any intervention which occurs *ex ante* (before the realization of an accident) is undertaken by a regulator  $\mathcal{R}$ . By contrast, any intervention which takes place *ex post* (after the realization of an accident) is undertaken by a judge  $\mathcal{J}$ . The view we adopt here is to consider the regulator and the judge as two arms of the same public authority.

**Transfers.** Transfers to the firm depend on its environmental performances. Let us denote by  $t_a$  and  $t_n$  the regulatory transfers to the firm following an accident or not.

Although our modeling uses the monetary nature of those rewards and punishments, a broader interpretation of those payments is available.<sup>13</sup> Bad environmental performances sometimes come also with damages to the fixed capital of the firm and to some stakeholders (like workers).<sup>14</sup> Costs may also be indirect and include tightened future regulations, increases in the number of costly environmental audits undertaken in the future, refusals by the government of authorizations and permits, and new taxes. A good management of environmental risk may also require the training and hiring of experts as permanent employees who improve know-how and affect positively other firm's activities.<sup>15</sup> These transfers can also be viewed as a black-box to model the long-term gains for the firm to develop a 'good reputation' or the long-term loss if the public authority decides to change the contractor after an accident. Rewards cover the firm's gains in reputation vis-à-vis its customers, potential contracting partners, the government, its shareholders and more generally the financial community as a whole.<sup>16,17</sup>

**Ex Ante Intervention by the Regulator.** Environmental regulators randomly monitor firms under their jurisdiction, trying to ensure that safety standards have been correctly implemented. When such investigation is launched, the regulator is able to discover the precautionary effort level effectively chosen by the firm and can force the firm to implement the standard of care  $e = 1$  when it did not initially perform such effort.<sup>18</sup> Importantly, whenever regulatory enforcement has taken place, one knows for sure that the firm ends up exerting a high effort.

<sup>13</sup>This broader interpretation is particularly useful in contexts, like in the U.S., where rewards for good environmental performances may be banned.

<sup>14</sup>Major industrial accidents like Bhopal in India or AZF in France had these features.

<sup>15</sup>On the discussion on the indirect costs and benefits of a good management of environmental risks, see Lesourd and Schilizzi (2001).

<sup>16</sup>To be completely correct with our modeling which stresses the social costs of those monetary transfers, one should also recognize a social cost of those non-monetary transfers. For instance, reputation gains may also create switching costs in the relationship between the firm and some of its contractual partners. Similarly, tightening future regulations may reduce entry on the market.

<sup>17</sup>Another interpretation is that the firm is given a base remuneration for its activities with an additional bonus to be given at the end of the contractual relationship if no accident took place.

<sup>18</sup>Of course, this perfect observability upon *ex ante* investigation is an extreme assumption. In practice regulators observe only how much resources are allocated within the firm to undertake care and whether maintenance, inspections and safety routines are respected. Those observables are related to the exact level of care but might actually be different.

The probability that such an ex ante regulatory audit is undertaken is  $p_e$ , interpreted as the intensity of regulatory enforcement to discover the firm's precautionary effort. Its social cost is  $C_{\mathcal{R},e}(p_e)$  with  $C_{\mathcal{R},e}(\cdot)$  increasing and convex and satisfying the Inada conditions  $C'_{\mathcal{R},e}(0) = 0$  and  $C'_{\mathcal{R},e}(1) = +\infty$  to ensure an interior solution in all configurations studied below.<sup>19</sup>

Throughout most of our analysis, we shall consider that the ex ante regulator is endowed with the power to verify the firm's claim about the value of its assets. By analogy with the audit of precautionary effort, let  $p_\theta$  be the intensity of the regulatory enforcement to discover the firm's wealth. Its social cost is  $C_{\mathcal{R},\theta}(p_\theta)$  with  $C_{\mathcal{R},\theta}(\cdot)$  increasing and convex and satisfying  $C'_{\mathcal{R},\theta}(0) = 0$  and  $C'_{\mathcal{R},\theta}(1) = +\infty$ .

Note that two interpretations of this ex ante enforcement stage are possible. In the first one, the regulator always scrutinizes the firm but discovers its effort choice or wealth only with some probability. In the second one, the regulator only investigates with some probability but always determines the effort level or wealth by doing so.

**Ex Post Intervention by the Judge.** In the event of an accident, a judge launches a lawsuit against the firm. The purpose of this lawsuit is to find out compensation for harmed third-parties. How much compensation can be taken away from the firm depends on the claimed value of its assets. We assume that the ex post investigation by the judge allows to discover the true value of these assets and the choice of safety care with probability  $q_\theta$  and  $q_e$  respectively, which depend on the amount of resources allocated to the judiciary branch. This ex post investigations have a social cost  $C_{\mathcal{J},\theta}(q_\theta)$  and  $C_{\mathcal{J},e}(q_e)$ , with  $C_{\mathcal{J},\cdot}(\cdot)$  being also increasing and convex and satisfying the Inada conditions  $C'_{\mathcal{J},\cdot}(0) = 0$  and  $C'_{\mathcal{J},\cdot}(1) = +\infty$ .<sup>20</sup>

**Contracts.** A regulatory contract requests the firm to report the value of its assets before this firm exerts any care. We denote by  $\{t_a(\hat{\theta}), t_n(\hat{\theta})\}$  the transfers to the firm if it claims having liability  $\hat{\theta} \in \Theta$  depending on whether an accident does occur or not. We denote by  $\{p_e(\hat{\theta}), p_\theta(\hat{\theta})\}$  (respectively  $\{q_e(\hat{\theta}), q_\theta(\hat{\theta})\}$ ) the probabilities of an ex ante (respectively ex post) audit of care and of the firm's assets.

By the Revelation Principle, there is no loss of generality in restricting the public authority to offer such direct mechanisms which ensure that the firm truthfully reveals the value of its assets. Incentive compatibility constraints will be studied later on. Note that these mechanisms are in fact characterized a priori by different probabilities of both kinds of audits together with ex post transfers (rewards or fines) that all depend on the firm's claim on its assets. Fines are used in the following cases: when the firm is audited, either ex ante or ex post, and the corresponding auditor figures out that the firm did not comply with the safety standard or has

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<sup>19</sup>Several studies have analyzed the cost of regulatory enforcement from an empirical viewpoint and shown some positive relationships between the frequency of such investigations and its administrative costs. See for instance, Epple and Visscher (1984) and Cohen (1985).

<sup>20</sup>Again, two possible interpretations of our model are possible. In the first one, the lawsuit is a sure event but is successful in unveiling the true assets or the choice of safety care only with some probability. In the second interpretation, the ex post investigation is itself random but always succeeds in either unveiling the true level of assets or discovering the safety care level.

understated its liabilities. When the firm is found shirking, either on care or on the value of its assets, the Maximal Punishment Principle applies.<sup>21</sup> The firm has to pay fines up to the value of its claimed assets to relax as much as possible incentive constraints. This remark helps us to significantly simplify the exposition of these constraints.

**Timing.** The sequence of events unfolds as follows:

- At date 0, nature draws the type  $\theta$  of the firm. The firm is privately informed about the assets' value.
- At date 1, the firm is offered a menu of contracts which, for all possible reports about its assets, stipulate transfers conditional on the occurrence of an accident and investigation policies.
- At date  $1^+$ , the firm announces  $\hat{\theta}$  or equivalently picks a contract among the menu offered and decides on the level of precautionary effort  $e$ .
- At date  $2^-$ , the regulator audits the firm with probabilities  $\{p_e(\hat{\theta}), p_\theta(\hat{\theta})\}$ . If an ex ante audit takes place, the regulator can verify the precautionary effort chosen by the firm. If this effort differs from the socially optimal one, the regulator can both enforce the high level of precautionary effort and impose fines to the firm for non-compliance.
- At date 2, an accident occurs with probability  $1 - \pi(e)$ .
- At date  $2^+$ , in the event of an accident, a lawsuit may or may not be initiated depending on the scenario investigated below. The judge discovers the value of the firm's assets and the firm's choice of effort with respective probabilities  $q_\theta(\hat{\theta})$  and  $q_e(\hat{\theta})$  and imposes a fine if the firm is found cheating. In all cases, transfers are paid according to the contract chosen at date  $1^+$ .

At this stage, let us emphasize that our setting implicitly assumes no separation of tasks between the regulator and the judge: both the safety care level and the firm's wealth can be audited by the regulator and the judge.

## 2.3 Incentive Constraints

To understand the nature of the different regulatory regimes that will be considered thereafter, it is useful to write down the firm's incentive constraints, which capture both the moral hazard and adverse selection sides of the incentive problem.

Before doing so, the following result is straightforward but helpful in simplifying the writing of these constraints: There is no need to check the assets of a firm claiming being of type  $\bar{\theta}$ , or  $p_\theta(\bar{\theta}) = q_\theta(\bar{\theta}) = 0$ . This would indeed mean incurring

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<sup>21</sup>See Becker (1968), Baron and Besanko (1984) and Laffont and Martimort (2002, Chapter 3).



the cost of an ex post investigation without relaxing any incentive constraint since, from Assumption 2, only understatement of assets is feasible.<sup>22</sup>

*The  $\underline{\theta}$ -firm.* First, consider a  $\underline{\theta}$ -firm with few assets. From Assumption 2, the only incentive issue is to induce this firm to comply with the standard of care. We can write its moral hazard incentive constraint as:

$$U(\underline{\theta}) \equiv \pi_1 t_n(\underline{\theta}) + (1 - \pi_1) t_a(\underline{\theta}) - \psi \geq [1 - p_e(\underline{\theta})] \{ \pi_0 t_n(\underline{\theta}) + (1 - \pi_0) [[1 - q_e(\underline{\theta})] t_a(\underline{\theta}) - q_e(\underline{\theta}) \underline{\theta}] \} - p_e(\underline{\theta}) (\psi + \underline{\theta}). \quad (1)$$

The left-hand side depicts the equilibrium payoff of this  $\underline{\theta}$ -firm once it complies with the standard. Even if an ex ante or an ex post investigation takes place, the auditors cannot detect any misconduct and the firm is not fined. By contrast, when this  $\underline{\theta}$ -firm shirks on the level of care, it may be detected ex ante with probability  $p_e(\underline{\theta})$ . In that case, it will be forced by the regulator to adopt the standard of due care and to bear the cost  $\psi$ . The firm is also heavily punished whatever the future realization of the environmental risk, i.e., the public authority imposes a net penalty equal to the firm's liability  $\underline{\theta}$ . Finally, if an accident occurs and the ex ante investigation has been unsuccessful, the mechanism may require an ex post investigation of effort for this  $\underline{\theta}$ -firm; with probability  $q_e(\underline{\theta})$ , this audit is successful and the firm is fined up to its liabilities.

Taking into account the limited liability constraint of a  $\underline{\theta}$ -firm, namely,

$$t_a(\underline{\theta}) \geq -\underline{\theta}, \quad (2)$$

the moral hazard incentive constraint (1) can be rewritten as:

$$U(\underline{\theta}) \geq R(p_e(\underline{\theta})) - \underline{\theta}, \quad (3)$$

where  $R(p_e) \equiv \left( \frac{\pi_0(1-p_e) - \pi_1 p_e}{\pi_1 - \pi_0(1-p_e)} \right) \psi$ . To exert the socially desirable effort level, the  $\underline{\theta}$ -firm must be given a liability rent  $R(p_e(\underline{\theta})) - \underline{\theta}$ .

Notice that if the probability of an ex ante investigation is sufficiently large, constraint (1) is trivially satisfied and the moral hazard problem disappears. In order to get rid of this uninteresting case, we shall assume that the ex ante investigation occurs not too frequently, i.e.,  $1 - \pi_1 < (1 - p_e(\underline{\theta}))(1 - q_e(\underline{\theta}))(1 - \pi_0)$  in the relevant range. This implies that one wants to increase as much as possible the fine paid by the firm if an accident occurs so that limited liability on the firm's side is a serious impediment to first-best regulation.<sup>23</sup>

*The  $\bar{\theta}$ -firm.* Let us now turn to the  $\bar{\theta}$ -firm. This firm may not only shirk by not adopting the standard of due care but it may also hide its assets to limit its exposure to liability payments if an accident occurs. This leads us to consider three incentive

<sup>22</sup>Indeed, given the focus on direct and truthful contracts, the firm will never lie about its assets level at equilibrium; hence the sole purpose of the investigation policies is to relax the firm's incentive constraints. See Laffont and Martimort (2002, Chapter 3) and the references therein.

<sup>23</sup>More formally, when  $1 - \pi_1 \geq (1 - p_e(\underline{\theta}))(1 - q_e(\underline{\theta}))(1 - \pi_0)$ , one can find transfers  $t_a(\underline{\theta})$  and  $t_n(\underline{\theta})$  which leave the firm with no rent and satisfy both the moral hazard incentive and limited liability constraints, making the problem trivial.

constraints:

- a pure moral hazard incentive constraint where the  $\bar{\theta}$ -firm might shirk only by adopting a low level of care;
- a pure adverse selection incentive constraint where the  $\bar{\theta}$ -firm adopts the standard but pretends to have low assets;
- a mixed incentive constraint where both deviations take place simultaneously.

First, note that the pure moral hazard incentive constraint of a  $\bar{\theta}$ -firm can be derived exactly as we did for a  $\underline{\theta}$ -firm. Given the  $\bar{\theta}$ -firm's liability constraint, namely,

$$t_a(\bar{\theta}) \geq -\bar{\theta}, \quad (4)$$

and the definition of the  $\bar{\theta}$ -firm's expected utility, we find:

$$U(\bar{\theta}) \equiv \pi_1 t_n(\bar{\theta}) + (1 - \pi_1) t_a(\bar{\theta}) - \psi \geq R(p_e(\bar{\theta})) - \bar{\theta}. \quad (5)$$

Second, the pure adverse selection incentive constraint prevents the  $\bar{\theta}$ -firm from understating its wealth given that it has chosen to comply with the standard of due care. After rearranging terms, this constraint writes as:

$$U(\bar{\theta}) \geq [1 - p_\theta(\underline{\theta})] [U(\underline{\theta}) - (1 - \pi_1) q_\theta(\underline{\theta}) \Delta\theta] - p_\theta(\underline{\theta}) (\bar{\theta} + \psi). \quad (6)$$

This pure adverse selection constraint can be interpreted in the following way. If a  $\bar{\theta}$ -firm understates its wealth while complying with the standard, with probability  $1 - p_\theta(\underline{\theta})$  it obtains the rent  $U(\underline{\theta})$  of a  $\underline{\theta}$ -firm if it is not found cheating by the ex ante regulator, but faces a probability  $(1 - \pi_1) q_\theta(\underline{\theta})$  of being fined up to the value of the hidden assets  $\Delta\theta$  if an accident takes place and it is audited ex post. This possibility reduces the rent associated with the understatement of wealth and thus relaxes (6).

Third, considering now the possibility of deviations on both effort and assets, we get, after rearranging terms, the mixed incentive constraint:

$$U(\bar{\theta}) \geq [1 - p_\theta(\underline{\theta})] [R(p_e(\underline{\theta})) - \underline{\theta}] - p_\theta(\underline{\theta}) [\bar{\theta} + \psi p_e(\underline{\theta})] - [1 - p_\theta(\underline{\theta})] q_\theta(\underline{\theta}) \{ (1 - \pi_0) [1 - p_e(\underline{\theta})] + (1 - \pi_1) p_e(\underline{\theta}) \} \Delta\theta. \quad (7)$$

In spirit, this is similar to the case of the pure adverse selection constraint. By cheating on its wealth and by shirking of safety care, the  $\bar{\theta}$ -firm earns the limited liability rent of the  $\underline{\theta}$ -firm only when it is unsuccessfully audited ex ante and ex post. In all the other cases, it may either have to disgorge the whole value of its assets (when one of the audits on wealth is successful) or part of this value (when it is convinced of shirking on safety care but the audits on assets have been unsuccessful).

The following lemma is directly obtained from the inspection of the incentive constraints (3), (5), (6) and (7).

**Lemma 1.** *It is always optimal to set  $q_e(\theta) = 0 \forall \theta \in \Theta$ .*

Indeed, that investigation probability does not affect any of the incentive constraints. The underlying reason is the following: The nature of the incentive problem is such that in the event of an accident the firm is fined up to the value of its assets. Checking ex post the choice of precaution effort does not allow to impose an additional penalty on the firm. Hence, the ex post audit of the firm's safety care level has no value. This clearly calls for a kind of partial separation of tasks of the ex ante regulator and the ex post judge. The former must audit both the technical (choice of precaution effort) as well as the financial (claimed value of assets) aspects of the firm, whereas the latter confines to the financial aspects.

## 2.4 Social Objectives

Optimal contracts are designed to maximize a social welfare function which incorporates the well-being of victims but also the cost of the incentive program (the cost of regulatory transfers and the administrative costs of the investigations). This objective writes as:

$$\mathcal{W} = \mathbb{E}_\theta \left\{ -(1 - \pi_1)D - [\pi_1 t_n(\theta) + (1 - \pi_1)t_a(\theta)] - \sum_{i=e,\theta} C_{\mathcal{R},i}(p_i(\theta)) - \sum_{i=e,\theta} C_{\mathcal{J},i}(q_i(\theta)) \right\},$$

where  $\mathbb{E}_\theta(\cdot)$  is the expectation operator with respect to the wealth level. Expressing this objective as a function of the utility levels left to both types of firms, we get:

$$\mathcal{W} = -(1 - \pi_1)D - \psi - \mathbb{E}_\theta \left\{ U(\theta) + \sum_{i=e,\theta} [C_{\mathcal{R},i}(p_i(\theta)) + C_{\mathcal{J},i}(q_i(\theta))] \right\}.$$

We thus see that the utility levels left to both types of firms should be reduced as much as possible to maximize social welfare. Summarizing, under asymmetric information, the problem becomes:

$$\begin{aligned} (\mathcal{P}) : \quad & \min_{\{U(\cdot), q(\cdot), p(\cdot)\}} \mathbb{E}_\theta \left\{ U(\theta) + \sum_{i=e,\theta} [C_{\mathcal{R},i}(p_i(\theta)) + C_{\mathcal{J},i}(q_i(\theta))] \right\} \\ & \text{subject to constraints (3), (5), (6), (7) and } U(\theta) \geq 0 \forall \theta, \end{aligned}$$

where we normalize the firm's outside opportunities to zero.

## 2.5 Preliminaries

We shall now proceed to the final simplifications of our setting.

To focus on the interesting cases, we will assume throughout the paper that the so-called limited liability rent  $R(p_e) - \theta$  is strictly positive for all  $(\theta, p_e)$  in the relevant domain. This condition implies that the  $\theta$ -firm participation constraint is implied by its limited liability and moral hazard incentive constraints which are compounded into (3). For future references, we highlight that the limited liability rent is decreasing in the firm's assets, i.e., firms which have more assets earn lower limited liability rents since, having to disgorge more cash in the event of an accident, they obtain a lower rent to perform a given level of care.

Since the firm's rent is socially costly, the moral hazard incentive constraint of the  $\underline{\theta}$ -firm will bind at equilibrium. We now focus on the incentive constraints of the  $\bar{\theta}$ -firm.

**Lemma 2.** *Consider that the moral hazard incentive constraint of the  $\underline{\theta}$ -firm (3) binds. Then, the moral hazard incentive constraint of a  $\bar{\theta}$ -firm cannot be the only binding incentive constraint for that firm.*

The intuition is immediate. If it were the case, then the different types of firms would be audited on their choice of safety care with the same probability (i.e.,  $p_e(\underline{\theta}) = p_e(\bar{\theta})$ ) and the  $\bar{\theta}$ -firm would have an incentive to cheat on its wealth, for the mere reason that the limited liability rent decreases with the level of assets revealed by the firm.

Moreover:

**Lemma 3.** *Consider that the moral hazard incentive constraint of the  $\underline{\theta}$ -firm (3) binds. Then, the pure adverse selection incentive constraint of the  $\bar{\theta}$ -firm (6) is more demanding than the mixed incentive constraint of that firm (7) if and only if:*

$$\frac{\psi/\Delta\pi}{\Delta\theta} \leq q_{\theta}(\underline{\theta}) \frac{1 - p_{\theta}(\underline{\theta})}{p_{\theta}(\underline{\theta})}. \quad (8)$$

In a nutshell, this condition summarizes the relative severity of the moral hazard and adverse selection problems. A large cost of effort  $\psi$  entails that the firm is reluctant to exert the high level of safety care; similarly, a low probability differential  $\Delta\pi$  implies that the firm's reward will weakly depend on the choice of precaution effort, again traducing a severe incentive moral hazard problem. By contrast, a large wealth differential  $\Delta\theta$  makes the adverse selection problem more stringent, as the  $\bar{\theta}$ -firm has thus strong incentives to understate its wealth. Roughly speaking, when  $\frac{\psi/\Delta\pi}{\Delta\theta}$  is small (respectively large) the adverse selection problem is more (respectively less) severe than the moral hazard one.

To conclude, different regimes appear depending on the relative severity of the moral hazard vs. the adverse selection problem of the  $\bar{\theta}$ -firm. Inside each regime, two possibilities have to be accounted for, depending on whether the pure moral hazard incentive constraint of that firm is binding or not.

### 3 Benchmarks

To better understand some of our results, it is useful to start looking at a few benchmarks in which the ability to audit the firm is limited .

#### 3.1 No Ex Ante Investigation

Let us start by assuming that the cost of an ex ante investigation is infinite, which forces to set  $p_{\theta}(\theta) = p_e(\theta) = 0$  for any  $\theta$ . According to Lemma 3, the relevant

incentive constraints for the  $\bar{\theta}$ -firm are its moral hazard and its adverse selection incentive constraints, which write respectively as follows:

$$U(\bar{\theta}) \geq R(0) - \bar{\theta}, \quad (9)$$

$$U(\bar{\theta}) \geq U(\underline{\theta}) - \Delta\theta q_{\theta}(\underline{\theta})(1 - \pi_1). \quad (10)$$

Straightforward manipulations show the following proposition.

**Proposition 1.** *Assume that only the ex post investigation is feasible. Then, an unconstrained regime always emerges, in which constraints (3) and (10) are binding. Only the  $\underline{\theta}$ -firm is investigated with a positive probability  $q_{\theta}^{ep}(\underline{\theta})$ :*

$$C'_{\mathcal{J},\theta}(q_{\theta}^{ep}(\underline{\theta})) = \frac{\nu}{1 - \nu} \Delta\theta(1 - \pi_1). \quad (11)$$

The judge's intervention only bears on the financial claims made by the firm. By increasing the frequency of its audit, the  $\bar{\theta}$ -firm which understates its assets will be caught lying more frequently in the event of an accident (which occurs with probability  $1 - \pi_1$  when the firm exerts the high level of safety care)

### 3.2 No Ex Post Investigation

Let us now suppose that the cost of an ex post investigation is infinite, which forces to set  $q_{\theta}(\theta) = 0$  for any  $\theta$ .<sup>24</sup> According to Lemma 3, the relevant incentive constraints for the  $\bar{\theta}$ -firm are its moral hazard and its mixed incentive constraints, which write respectively as follows:

$$U(\bar{\theta}) \geq R(p_e(\bar{\theta})) - \bar{\theta}, \quad (12)$$

$$U(\bar{\theta}) \geq [1 - p_{\theta}(\underline{\theta})] [R(p_e(\underline{\theta})) - \underline{\theta}] - p_{\theta}(\underline{\theta})(\bar{\theta} + \psi p_e(\underline{\theta})). \quad (13)$$

Depending on whether (13) only or both (13) and (12) are binding, we have two cases to consider, which we label respectively the unconstrained and the constrained regimes. We shall focus first on the unconstrained regime.

**Proposition 2.** *Assume that only the ex ante investigation is feasible. Then, an unconstrained regime, in which constraints (3) and (13) are binding, emerges provided that  $R(0) \leq [R(p_{\theta}^{ea}(\underline{\theta})) + \Delta\theta][1 - p_{\theta}^{ea}(\underline{\theta})] - p_{\theta}^{ea}(\underline{\theta})p_e^{ea}(\underline{\theta})\psi$ . Only the  $\underline{\theta}$ -firm is investigated with positive probabilities  $p_e^{ea}(\underline{\theta})$  and  $p_{\theta}^{ea}(\underline{\theta})$  such that:*

$$C'_{\mathcal{R},e}(p_e^{ea}(\underline{\theta})) = -\frac{1}{1 - \nu} R'(p_e^{ea}(\underline{\theta})) + \frac{\nu}{1 - \nu} p_{\theta}^{ea}(\underline{\theta}) [R'(p_e^{ea}(\underline{\theta})) + \psi], \quad (14)$$

$$C'_{\mathcal{R},\theta}(p_{\theta}^{ea}(\underline{\theta})) = \frac{\nu}{1 - \nu} [R(p_e^{ea}(\underline{\theta})) + \Delta\theta + \psi p_e^{ea}(\underline{\theta})]. \quad (15)$$

*Proof.* See Appendix A.1. □

The ex ante audit probabilities satisfy a marginal cost equal marginal benefit rule. Increasing the frequency of the ex ante audit on safety care allows to reduce

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<sup>24</sup>Remind that  $q_e(\theta) = 0$  is optimal.

the limited liability rent of a  $\underline{\theta}$ -firm and to reduce the  $\bar{\theta}$ -firm's incentives to exert a low precaution effort and to understate its wealth. By contrast, increasing the frequency of the ex ante audit on the firm's financial claim only reduces the  $\bar{\theta}$ -firm's incentives to understate its liabilities.

In Appendix A.1, we solve the unconstrained regime. Roughly speaking, the lessons of the unconstrained regime extend those of the constrained one. One common feature of both regimes is that the probability of an ex ante investigation decreases with the claimed assets. However, when the uncertainty on the firm's assets is small enough, the gain from shirking on safety care is greater than the gain from lying on assets value. Hence, the pure moral hazard incentive constraint of a  $\bar{\theta}$ -firm is necessarily also binding. To relax this constraint, the probability of an ex ante investigation of a  $\bar{\theta}$ -firm is now positive although lower than when assets are common knowledge. Because (12) is now binding, the multiplier  $\lambda$  of the mixed incentive constraint (13) is less than  $\nu$ . Compared with what happens in an unconstrained regime, this reduces the marginal benefits of increasing the probability of both an ex post and an ex ante investigation of a  $\underline{\theta}$ -firm. Indeed, now the mixed incentive constraint can be relaxed by using the probability of auditing ex ante the  $\bar{\theta}$ -firm.

In the remaining analysis, since they share very similar qualitative features, we shall focus on the unconstrained regimes only.

## 4 The Regulator and the Judge

Let us now turn to the full-fledged model where the claim of the firm on its assets can possibly be checked ex post at some cost by the judge. The main lesson of the costly state verification models à la Townsend (1978)-Gale and Hellwig (1985) applies to our framework: The threat of being punished when caught lying reduces the firm's incentives to understate the value of its assets. The main question we address in this section is thus: How the ex ante and ex post investigation policies ought to be optimally combined?

**Adverse-selection-biased incentive problem.** We first consider the case in which condition (8) holds so that the adverse selection constraint of the  $\bar{\theta}$ -firm is more demanding than the mixed constraint. In a nutshell, the adverse selection problem is more severe than the moral hazard one. The following proposition is easily obtained.

**Proposition 3.** *Consider that (8) holds. Then, in an unconstrained regime, only the  $\underline{\theta}$ -firm is audited with probabilities  $p_e^*(\underline{\theta})$ ,  $p_\theta^*(\underline{\theta})$  and  $q_\theta^*(\underline{\theta})$  such that:*

$$\begin{aligned} C'_{\mathcal{R},e}(p_e^*(\underline{\theta})) &= -\frac{1}{1-\nu}R'(p_e^*(\underline{\theta})) + \frac{\nu}{1-\nu}p_\theta^*(\underline{\theta})R'(p_e^*(\underline{\theta})), \\ C'_{\mathcal{R},\theta}(p_\theta^*(\underline{\theta})) &= \frac{\nu}{1-\nu}[R(p_e^*(\underline{\theta})) + \Delta\theta + \psi] - \frac{\nu}{1-\nu}\Delta\theta(1-\pi_1)q_\theta^*(\underline{\theta}), \\ C'_{\mathcal{J},\theta}(q_\theta^*(\underline{\theta})) &= \frac{\nu}{1-\nu}\Delta\theta(1-\pi_1)(1-p_\theta^*(\underline{\theta})). \end{aligned}$$

**Moral-hazard-biased incentive problem.** By contrast, when condition (8) does not hold, the mixed constraint is more demanding than the adverse selection one. Then, we obtain the following proposition.

**Proposition 4.** *Consider that (8) does not hold. Then, in an unconstrained regime, only the  $\underline{\theta}$ -firm is audited with probabilities  $p_e^{**}(\underline{\theta})$ ,  $p_\theta^{**}(\underline{\theta})$  and  $q_\theta^{**}(\underline{\theta})$  such that:*

$$\begin{aligned} C'_{\mathcal{R},e}(p_e^{**}(\underline{\theta})) &= -\frac{1}{1-\nu}R'(p_e^{**}(\underline{\theta})) + \frac{\nu}{1-\nu}p_\theta^{**}(\underline{\theta})[R'(p_e^{**}(\underline{\theta})) + \psi] - \frac{\nu}{1-\nu}\Delta\theta\Delta\pi q_\theta^{**}(\underline{\theta})(1-p_\theta^{**}(\underline{\theta})), \\ C'_{\mathcal{R},\theta}(p_\theta^{**}(\underline{\theta})) &= \frac{\nu}{1-\nu}[R(p_e^{**}(\underline{\theta})) + \Delta\theta + \psi p_e^{**}(\underline{\theta})] - \frac{\nu}{1-\nu}\Delta\theta[1-\pi_1 + \Delta\pi p_e^{**}(\underline{\theta})]q_\theta^{**}(\underline{\theta}), \\ C'_{\mathcal{J},\theta}(q_\theta^{**}(\underline{\theta})) &= \frac{\nu}{1-\nu}\Delta\theta[1-\pi_1 + \Delta\pi p_e^{**}(\underline{\theta})](1-p_\theta^{**}(\underline{\theta})). \end{aligned}$$

**Comparison.** Let us first compare the previous two cases.

**Proposition 5.** *If the moral hazard incentive problem is more severe than the adverse selection one, then:*

- *the ex ante regulator specializes more in the technical audit and less in the financial one, i.e.,  $p_e^{**}(\underline{\theta}) \geq p_e^*(\underline{\theta})$  and  $p_\theta^{**}(\underline{\theta}) \leq p_\theta^*(\underline{\theta})$ ;*
- *the ex post judge specializes more in the financial audit, i.e.,  $q_\theta^{**}(\underline{\theta}) \geq q_\theta^*(\underline{\theta})$ .*

*The reverse holds when the adverse selection incentive problem is more severe than the moral hazard one.*

We now want to understand the impact of complementing the ex ante regulation with an ex post judicial intervention.

**Proposition 6.** *Complementing the ex ante regulation with an ex post intervention reduces the ex ante audit on effort but has an ambiguous impact on the ex ante audit of the firm's wealth.*

## 5 Extensions

### 5.1 Functional Separation

We now study a more constrained situation in which the ex ante regulator is bound to intervene on the technical aspects whereas the ex post judge's intervention concerns only the financial aspects. This coincides with a situation in which there is a full functional separation of the various auditors. In terms of our model, this amounts to assuming that  $p_\theta(\theta) = q_e(\theta) = 0$  for all claim  $\theta \in \Theta$ .

According to Lemma 8, the adverse selection problem is more demanding than the moral hazard one, and the relevant constraint for a  $\bar{\theta}$ -firm are:

$$\begin{aligned} U(\bar{\theta}) &\geq R(p_e(\bar{\theta})) - \bar{\theta}, \\ U(\bar{\theta}) &\geq U(\underline{\theta}) - (1-\pi_1)q_\theta(\underline{\theta})\Delta\theta. \end{aligned} \tag{16}$$

The following proposition is easily obtained.

**Proposition 7.** *Consider functional separation between the ex ante regulator and the ex post judge and an unconstrained regime in which constraints (3) and (16) are binding. Only the  $\underline{\theta}$ -firm is audited with probabilities  $p_e^{fs}(\underline{\theta})$  and  $q_\theta^{fs}(\underline{\theta})$  such that:*

$$\begin{aligned} C'_{\mathcal{R},e}(p_e^{fs}(\underline{\theta})) &= -\frac{1}{1-\nu}R'(p_e^{fs}(\underline{\theta})), \\ C'_{\mathcal{J},\theta}(q_\theta^{fs}(\underline{\theta})) &= (1-\pi_1)\Delta\theta. \end{aligned}$$

In that case, there is a clear separation between the tasks of the regulator and the judge. Any change in the cost of one kind of investigation has only an impact on the probability of using that particular investigation.

It is worth describing the optimal transfers for both types. For a  $\bar{\theta}$ -firm, whose limited liability and pure adverse selection incentive constraints are binding, we find the following transfers:

$$\begin{aligned} t_a^{fs}(\bar{\theta}) &= -\bar{\theta}, \\ t_n^{fs}(\bar{\theta}) &= -\bar{\theta} + \underbrace{\frac{(1-p_e^{fs}(\underline{\theta}))\psi}{\pi_1-\pi_0(1-p_e^{fs}(\underline{\theta}))}}_{\text{Moral hazard incentive reward for a } \underline{\theta}\text{-firm}} + \underbrace{\frac{\Delta\theta}{\pi_1} \left[ 1 - (1-\pi_1)q_\theta^{fs}(\underline{\theta}) \right]}_{\text{Adverse selection incentive rewards}}. \end{aligned}$$

These transfers decompose the role of the regulator and the judge. Everything happens as if the  $\bar{\theta}$ -firm was now always forced to pay fines up to the value of its assets when an accident takes place but then receives an extra reward for a good environmental performance. This extra reward can be decomposed into two pieces: First, the incentive reward offered to a  $\underline{\theta}$ -firm to solve its moral hazard problem; second, a pure adverse selection reward to induce truth-telling. The first of these rewards is reduced through an ex ante investigation whereas the second one is reduced by the threat of an ex post prosecution.

In an unconstrained regime, the sum of these two rewards suffices to solve the moral hazard problem of a  $\bar{\theta}$ -firm.

## 5.2 Immunization

Suppose now that the judge intervenes only after an accident and the regulator did not intervene ex ante. The two arms intervene thus to solve different incentive problems and in different states of nature. We call this the ‘immunization requirement’.

As in the previous section, the adverse selection constraint (6) which writes as

$$U(\bar{\theta}) \geq U(\underline{\theta}) - (1-\pi_1)[1-p_e(\underline{\theta})]q_\theta(\underline{\theta})\Delta\theta \quad (17)$$

is binding at the optimum. Note the difference with the case of functional separation: with immunization, the ex post judge is bound to intervene only when the ex ante regulator has not.

Then, we obtain the following proposition.

**Proposition 8.** *Consider the immunization requirement in conjunction with func-*



tional separation and an unconstrained regime in which constraints (3) and (17) are binding. Only the  $\underline{\theta}$ -firm is audited with probabilities  $p_e^{im}(\underline{\theta})$  and  $q_{\theta}^{im}(\underline{\theta})$  such that:

$$C'_{\mathcal{R},e}(p_e^{im}(\underline{\theta})) = -\frac{1}{1-\nu}R'(p_e^{im}(\underline{\theta})) - \frac{\nu}{1-\nu}(1-\pi_1)q_{\theta}^{im}(\underline{\theta})\Delta\theta, \quad (18)$$

$$C'_{\mathcal{J},\theta}(q_{\theta}^{im}(\underline{\theta})) = \frac{\nu}{1-\nu}(1-\pi_1)(1-p_e^{im}(\underline{\theta}))\Delta\theta. \quad (19)$$

Remember that the  $\bar{\theta}$ -firm prefers to hide its wealth than to shirk on the level of care because doing so reduces the probability of accident and thus the overall probability of liability exposure. Decreasing the probability of the regulator's monitoring increases the likelihood that the judge intervenes ex post. This increases the threat of being fined if an accident occurs.

Although both kinds of intervention help relaxing incentive constraints, the regulator is relatively inefficient in inducing the  $\bar{\theta}$ -firm to disgorge cash. The judge is instead crucial in doing so. However, the judge intervenes only when an ex ante investigation did not take place, i.e., with probability  $(1-\pi_1)(1-q(\underline{\theta}))$ . Condition (19) reflects the fact that the marginal benefit of an ex post investigation depends on the probability that an ex ante investigation did not take place.

With immunization, everything happens as if, following the regulator's intervention, the firm pays a fine  $\underline{\theta}$  that can be raised up to  $\bar{\theta}$  if the judge intervenes. To reinforce this intuition, let us describe the optimal transfers. Given that both the limited liability constraint (2) and the moral hazard incentive constraint (3) of a  $\underline{\theta}$ -firm are binding, we find:

$$t_a^{im}(\underline{\theta}) = -\underline{\theta}, \quad (20)$$

$$t_n^{im}(\underline{\theta}) = -\underline{\theta} + \frac{(1-p_e^{im}(\underline{\theta}))\psi}{\pi_1 - \pi_0(1-p_e^{im}(\underline{\theta}))}. \quad (21)$$

For a  $\bar{\theta}$ -firm, given that both the limited liability constraint (4) and the pure adverse selection constraint (6) are binding, we find:

$$t_a^{im}(\bar{\theta}) = -\bar{\theta}, \quad (22)$$

$$t_n^{im}(\bar{\theta}) = -\bar{\theta} + \underbrace{\frac{(1-p_e^{im}(\underline{\theta}))\psi}{\pi_1 - \pi_0(1-p_e^{im}(\underline{\theta}))}}_{\text{Moral hazard incentive reward for a } \underline{\theta}\text{-firm}} + \underbrace{\frac{\Delta\theta}{\pi_1} [1 - (1-\pi_1)(1-p_e^{im}(\underline{\theta}))q_{\theta}^{im}(\underline{\theta})]}_{\text{Adverse selection incentive reward}} \quad (23)$$

These transfers can easily be interpreted. Everything happens as if the maximal fine imposed on a  $\bar{\theta}$ -firm was equal to its assets but there existed a reward for a good environmental performance incorporating the information rent withdrawn by this firm from private knowledge of its assets. Indeed, the right-hand side of (23) can be decomposed into two pieces: first, the moral hazard incentive reward which induces a high level of care from the  $\underline{\theta}$ -firm; second, the adverse selection incentive reward which facilitates truth-telling. Although the first of these terms is reduced with an ex ante investigation, the second one increases with it.

In this setting, some substitutability between the regulator and the judge ap-

pears.<sup>25</sup> When the regulator benefits from a better supervision technology ( $C'_{\mathcal{R},e}(\cdot)$  being lower), an ex ante investigation becomes easier,  $p_e^{im}(\underline{\theta})$  increases and the marginal benefit from an ex post investigation decreases (from (19)). Increasing the frequency of ex ante intervention makes it less valuable to call the judge ex post. Reciprocally, when the ex post investigation technology of the judge improves ( $C'_{\mathcal{J},\theta}(\cdot)$  being lower),  $q_{\theta}^{im}(\underline{\theta})$  increases and this decreases the marginal benefit from auditing the firm ex ante (from (18)). Altogether, these results show the substitutability between the two arms of enforcement. Although both are jointly used to improve incentives, the better one instrument, the less used is the other, at least as long as the regulatory intervention immunizes the firm against ex post prosecution.

## 6 Conclusion

We have developed a model to study the respective roles of the regulator and the judge in the control of environmental risk. Our starting point is that there exists a separation of tasks between the regulator who controls safety care ex ante, i.e., before any accident realizes, and the judge who intervenes ex post to find out the true value of the firm's assets for compensation. Although different in nature and in timing, both instruments are useful in providing incentives to the firm. However, the precise interaction between the regulator and the judge depends on the rule determining the Courts' intervention.<sup>26</sup>

The first two scenarii we have explored in this paper could be interpreted in terms of real world legal principles.

In our first scenario, the firm is insulated from the perspective of a lawsuit if it has already been inspected by a regulator, which ensures that the high level of effort has been exerted. Considering the fact that the firm is not prosecuted if an accident occurs and that it must have exerted a high level of care, this first scenario has something in common with the *negligence rule* in the law doctrine where injurers are not held liable for the damage they have caused if they have complied with a standard of due care.

In our second scenario, the judge may intervene if an accident takes place even if the regulator did. This has something in common with the *strict liability rule* in the law doctrine where injurers are held liable for the damage they have caused whatever the care they have exerted.

With this comparison in mind, we can reinterpret our main results in the following way. The immunization of firms from legal investigation that follows a regulatory inspection under the negligence rule creates a substitutability between the regulator and the judge. Instead, under strict liability, the regulator and the judge do not

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<sup>25</sup>Indeed, differentiating (19) leads to:

$$\frac{dp_*^{ep}(\underline{\theta})}{dq_*^{ep}(\underline{\theta})} = -\frac{1}{C''_{\mathcal{J}}(p_*^{ep}(\underline{\theta}))} \frac{\nu}{1-\nu} (1-\pi_1)\Delta\theta < 0.$$

<sup>26</sup>We did not rank the policies described through scenarii 1 to 3. Obviously, the greatest social welfare would be obtained when using the highest number of instruments, hence under *conditioning*, as long as interventions do not involve fixed costs ( $C_{\mathcal{R}}(0) = 0$  and  $C_{\mathcal{J}}(0) = 0$ ).

interact.

Our model provides thus strong predictions on the extent of ex ante and ex post enforcements. A negative correlation between expenditures/investigations of both branches is expected under the negligence rule whereas expenditures/investigations in the judiciary branch are not correlated with the regulatory expenditures/investigations under strict liability. We are not aware of any such empirical study but such endeavour would certainly be worth undertaking.

From a theoretical perspective, our model could be extended along several lines. First, risk-aversion on the firms' side may also be an important concern. The presence of the regulator and the judge would affect the standard trade-off between insurance and incentives under moral hazard. We feel confident that the general lessons of our work will carry over to those environments.

Second, the legal procedures by which the judge uncovers assets and pierces the corporate veil have been modeled here as a black-box. Much should be made to understand this stage of the analysis in more details.

We also found that, in the event of an accident, providing the judge with the possibility to run a separate expertise about the firm's choice of precautionary effort is useless. This calls for some sort of separation between the regulatory tasks and the legal intervention: the regulator limits its intervention to the 'technical' aspects of the underlying risk (i.e., the care exerted by the firm) and the judge focuses on 'financial' aspects, i.e., the firm's collectable wealth. Clearly, further research is warranted in order to refine these results and to reach a better understanding of the interaction between ex ante and ex post interventions.

For instance, we have taken for granted the cooperation between the regulator and the judge. These restrictions are reasonable approximations of real-world institutions. However, they abstract away from political economy considerations of conflict of interests between regulators and judges. Introducing such considerations should allow us to build a more satisfactory theory of the organization of the control of risky industrial activities and of the separation or integration of regulators and judges.<sup>27</sup> We plan to investigate those issues in future research.

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<sup>27</sup>See Hiriart, Martimort and Pouyet (2005) for some analysis along these lines.

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# A Appendix

## A.1 Proof of Proposition 2

**Unconstrained regime.** Consider that only constraints (3) and (13) are binding. The optimal contract is solution of the following problem:

$$\begin{aligned} \min_{p_e(\underline{\theta}), p_\theta(\underline{\theta})} A \equiv & \nu \{ [1 - p_\theta(\underline{\theta})] [R(p_e(\underline{\theta})) - \underline{\theta}] - p_\theta(\underline{\theta})(\bar{\theta} + \psi p_e(\underline{\theta})) \} \\ & + (1 - \nu) \{ R(p_e(\underline{\theta})) - \underline{\theta} + C_{\mathcal{R},e}(p_e(\underline{\theta})) + C_{\mathcal{R},\theta}(p_\theta(\underline{\theta})) \}. \end{aligned}$$

Solving for the first-order conditions yields the investigation probabilities stated in Proposition 2. The second-order conditions are satisfied provided that:  $\partial^2 A / \partial p_\theta(\underline{\theta})^2 \geq 0$ , which always holds thanks to the convexity of the cost functions;  $\partial^2 A / \partial p_e(\underline{\theta})^2 \geq 0$ , which always holds since  $R''(\cdot) > 0$ ;  $\partial^2 A / \partial p_\theta(\underline{\theta})^2 \partial^2 A / \partial p_e(\underline{\theta})^2 \geq (\partial^2 A / \partial p_\theta(\underline{\theta}) \partial p_e(\underline{\theta}))^2$ , which holds when costs are sufficiently convex.

Finally, the unconstrained regime holds as long as:

$$R(0) \leq (1 - p_\theta(\underline{\theta})) [R(p_e(\underline{\theta})) + \Delta\theta] - p_\theta(\underline{\theta}) [\bar{\theta} + \psi p_e(\underline{\theta})].$$

**Constrained regime.** In a constrained regime, the moral hazard constraint of a  $\bar{\theta}$ -firm (12) is also binding. The optimal contract solves:

$$\begin{aligned} \min_{p_e(\cdot), p_\theta(\cdot)} \mathbb{E}_\theta \{ & U(\theta) + C_{\mathcal{R},e}(p_e(\theta)) + C_{\mathcal{R},\theta}(p_\theta(\theta)) \}, \\ \text{s.t. } & U(\theta) = R(p_e(\theta)) - \theta, \forall \theta, \\ & U(\bar{\theta}) = (1 - p_\theta(\underline{\theta})) U(\underline{\theta}) - p_\theta(\underline{\theta}) (\bar{\theta} + \psi p_e(\underline{\theta})). \end{aligned}$$

Define  $\tilde{R}(\theta) = R(p_e(\theta))$  and  $h = C_{\mathcal{R},e}(R^{-1})$ . With this change of variables, we can express the previous optimization problem as follows:

$$\begin{aligned} \min_{\tilde{R}(\cdot), p_\theta(\underline{\theta})} \mathbb{E}_\theta \{ & \tilde{R}(\theta) + h(\tilde{R}(\theta)) \}, \\ \text{s.t. } & (1 - p_\theta(\underline{\theta})) (\tilde{R}(\underline{\theta}) - \underline{\theta}) - p_\theta(\underline{\theta}) [\bar{\theta} + \psi R^{-1}(\tilde{R}(\underline{\theta}))] = \tilde{R}(\bar{\theta}) - \bar{\theta}. \end{aligned}$$

This is a convex problem provided that  $h$  is convex, which amounts to  $C''_{\mathcal{R},e} / C'_{\mathcal{R},e} \geq R''$ , which holds provided, again, that costs are sufficiently convex.

Denote by  $\lambda$  the multiplier associated to the equality constraint in the previous optimization problem. Rearranging the first-order conditions, we obtain:

$$\begin{aligned} C'_{\mathcal{R},e}(p_e(\bar{\theta})) &= -R'(p_e(\bar{\theta})) \left( 1 - \frac{\lambda}{\nu} \right), \\ C'_{\mathcal{R},e}(p_e(\underline{\theta})) &= -R'(p_e(\underline{\theta})) + \frac{\lambda}{1 - \nu} [-(1 - p_\theta(\underline{\theta})) R'(p_e(\underline{\theta})) + p_\theta(\underline{\theta}) \psi], \\ C'_{\mathcal{R},\theta}(p_\theta(\underline{\theta})) &= \frac{\lambda}{1 - \nu} [R(p_e(\underline{\theta})) + \Delta\theta + \psi p_e(\underline{\theta})]. \end{aligned}$$

$\lambda$  is obtained by using the equality constraint for the values of the investigation

probabilities defined above. This interior solution is the solution of the optimization problem provided that  $\lambda \leq \nu$ . Otherwise, a corner solution emerges with  $p_e(\bar{\theta}) = 0$ , and we are back to the unconstrained regime.