OPTIMAL LIABILITY SHARING AND COURT ERRORS: AN EXPLORATORY ANALYSIS*

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October 2009

Abstract:

We focus in this paper on the effects of court errors on the optimal sharing of liability between firms and financiers, as an environmental policy instrument. Using a structural model of the interactions between firms, financial institutions, governments and courts we show, through numerical simulations, the distortions in liability sharing between firms and financiers that the imperfect implementation of government policies implies. We consider in particular the role played by the efficiency of the courts in avoiding Type I (finding an innocent firm guilty of inappropriate care) and Type II (finding a guilty firm innocent of inappropriate care) errors. This role is considered in a context where liability sharing is already distorted (when compared with first best values) due not only to the courts' own imperfect assessment of safety care levels exerted by firm but also to the presence of moral hazard and adverse selection in financial contracting, as well as of non-congruence of objectives between firms and financiers on the one hand and social welfare maximization on the other. Our results indicate that an increase in the efficiency of the court system in avoiding errors raises safety care levels, thereby reducing the probability of accident, and allowing the social welfare maximizing government to impose a lower liability [higher] share for firms [financiers] as well as a lower standard level of care.

1. INTRODUCTION

The diffusion of industrial and environmental risks has stirred an important debate about the proper instruments to implement public policies toward environmental protection and industrial safety. Two such instruments are the distribution of responsibilities and liabilities, should an accident occur, among the different actors involved directly or indirectly in risky activities and the definition of proper plant-level care level and safety activities.

Legislators typically impose a liability regime, either a strict one or a negligence-based one or both, and a wide range of plant-level regulations[1] relative to environmental and/or industrial risks. The objective is to find the combination of liability rules and safety regulation and standards to be imposed on producers and operators as well as on other stakeholders in order to attain, though the level of care that the latter are incentivized to choose, the socially efficient level of environmental and industrial risks. Achieving the right balance of instruments is a highly complex task.

Contributors to the debate have discussed theoretical properties of the joint use of the above two instruments, namely a liability regime, including the liability sharing formula, and a regulatory standard of care, in an asymmetric information framework given that the firms' preventive care measures are often difficult to observe and verify.[2]

From an economic perspective, a system of strict or negligence-based liability for industrial accidents together with a liability sharing rule among stakeholders can be seen as an instrument to internalise damage and to alleviate the judgement proof problem, which appears when the firm involved lacks the resources to pay for the damage it has caused. The assignment of liability, a generalization of both compulsory insurance and extended liability provisions under limited liability,[3] provides potentially liable parties

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[1] For instance, Trebilcock and Winter (1997) discuss the case of accident in nuclear power production for which the Price–Anderson Act imposes strict liability in addition to a wide range of plant-level regulations by the Nuclear Regulatory Commission.

[2] Shavell (1984); Kolstad, Ulen, Johnson (1990); Burrows (1999); Schmitz (2000); Innes (2004).

[3] The connection between ex post liability effects and ex ante prevention behaviour is stressed by the law and economics literature, for instance with respect to the jurisprudence surrounding the CERCLA. See Calabresi (1970); Shavell (1987), Boyer and Laffont (1997), Boyer and Porrini (2001, 2006).

with incentives to require, to induce and/or to exert proper care: an ex post liability system induces ex ante investments in care.

We wish to illustrate in this paper the incomplete information efficient distortions (from the first-best values obtained under full, albeit imperfect information) in the liability sharing formula and the standard of care. We propose an extended principal-agent liability model to analyze the distribution of liability shares among firms and financiers (insurers or bankers). The law and economics literature represents principal-agent liability as a framework where rational self-interested agents choose their preventive care level under the monitoring activities of a principal.[4] We widen the traditional framework by adopting the legislator's point of view in determining the liability sharing rule between firms and financiers and the standard of care in order to maximize social welfare, taking into account the asymmetric information (moral hazard and adverse selection) present in financial contracting as well as the existence of court errors in finding a firm guilty or not of negligence. Hence, we consider the relationships between four actors or stakeholders in the determination of the probability of environmental/industrial accidents: firms, financiers, government and courts.[5] An important specific contribution of this paper is to take a first look at the impact of court efficiency in avoiding judicial errors on the liability sharing formula and the standard of care.

In the next section, we discuss the implementation of liability sharing among firms and financiers through financial responsibility, lenders' liability provisions and jurisprudence in the American and European systems. In section 3, we discuss the effects of court errors in the context of achieving an efficient environmental policies choice of instruments. Section 4 is devoted to modelling the interactions between governments, firms, financiers and courts in the determination of the probability of accident, in a context characterized by moral hazard and adverse selection, an imperfect court system, and the non-congruence of objectives between firms and financiers on the one hand and a social

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[4] See Polinsky (2003) for standard presentation and discussion of such frameworks. Daughety and Reinganum (2003) proposed to widen the standard law and economics framework by assuming, in reference to product liability, that the market conditions and the tort system interact to affect the decision on care levels.

[5] See also Boyer and Porrini (2008).

welfare maximizing benevolent government on the other. We present, in Section 5, a simplified example, which incorporates the main characteristics and constraints of the analytically (too) complex interactions between the four stakeholders. We perform, in Section 6, a sensitivity analysis of the impact on the liability sharing formula, on the standard level of care, and on the levels of the other endogenous variables (exerted care level, probability of accident, probability of suing, and probability of conviction) of variations in the efficiency of the court system and of other parameters of interest such as the profitability of the firm's project or activities, the cost of care activities, the efficiency of care in reducing the probability of accident, the cost of suing, and the social cost of public funds. We conclude in Section 7.

2. LIABILITY SHARING AMONG FIRMS AND FINANCIERS: US AND EU

Civil liability for environmental damages has become a relevant instrument of environmental policy. In the US, the issue of environmental liability emerged some thirty years ago with several important pollution cases unravelling and, at the same time, an increased number of small enterprises entering risky sectors.[6] Congress enacted the *Comprehensive Environmental Response, Compensation and Liability Act* (CERCLA) in 1980 and a whole range of amendments in the following years, in order to cope with the "decontamination" of polluted sites by creating a Superfund for quick relief and remedy action once an accident has occurred and by recovering the clean-up and compensation costs from the liable parties.[7]

The liable parties include by law the past owners and the operators of the affected sites, as well as the current owners and operators, the generators of dangerous polluting materials stored on those sites, and the carriers of such material. Hence, the system is characterised by the retroactivity of liabilities and the involvement of many liable parties, the so-called Potentially Responsible Parties.

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[6] See Ringleb and Wiggins (1990).
[7] CERCLA covers damages on the specified sites, resulting in particular from the contamination produced by dangerous activities, as well as damages to natural resources. The Superfund allows decontaminating the sites included in a national list, the National Priority List (NPL), with money being primarily collected from taxes on oil and oil-derived product

Regarding the European experience, the *Directive on Environmental Liability with Regard to the Prevention and Remedying of Environmental Damage*[8] states: "The prevention and remedying of environmental damage should be implemented through the furtherance of the 'polluter pays' principle', as indicated in the Treaty and in line with the principle of sustainable development. The fundamental principle of this Directive should therefore be that an operator whose activity has caused the environmental damage or the imminent threat of such damage is to be held financially liable, in order to induce operators to adopt measures and develop practices to minimise the risks of environmental damage so that their exposure to financial liabilities is reduced."

From a law and economics analysis viewpoint, these ex post systems of liability could provide firms with optimal incentives to undertake ex ante safety measures and, in this way, could induce firms to internalize the full costs associated with accidents.[9] However, environmental damages are often very large and it is not uncommon that they exceed the resources of the responsible firm. The liability triggers the bankruptcy of the firm: the so called "judgement proof"[10] problem, under which residual damages remain externalised and uncompensated, thereby reducing the ex ante incentives for care and therefore the exerted level of care falls below the optimal level. One way by which environmental laws aim to remedy such judgement proof problem is to extend liability for residual damages to parties that are somewhat related to the firm.

In America, in spite of a secured interest exemption clause protecting financial institutions holding instruments of ownership on the firm's assets, the courts have repeatedly considered secured lenders as owners or operators, insofar as their involvement in the firm exceeded the level warranted to secure their interest.[11]

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[8] Directive 2004/35/CE of the European parliament and of the Council of 21 April 2004 on environmental liability with regard to the prevention and remedying of environmental damage, *Official Journal of the European Union*, L143/56, 30/4/04.

[9] See footnotes 2 and 3 above.

[10] See Shavell (1986).

[11] See for instance the following major court cases: United States vs. Mirabile (15, Environmental Law Reports 20, 994 (E.D. Pa 1985)); United States vs. Maryland Bank and Trust (632 F. Su 573 (d. Md. 1986)); United States vs. Fleet Factors Corp. (901 F. 2d 1550 (11th Cir. 1990), cert. Denied, 498 US 1046 (1991)). The critical level of involvement was lowered over time and lender's liability turned out to

In Europe, the article 14 of the Directive 2004/35/CE states: "Member States shall take measures to encourage the development of financial security instruments and markets by the appropriate economic and financial operators, including financial mechanisms in case of insolvency, with the aim of enabling operators to use financial guarantees to cover their responsibilities under this Directive".

Extending liability could, under certain conditions, be efficient given the possibility of the parties, through their contractual relationship, to restore the firm's incentive to take the "optimal" level of care. Under full information, the full extension of ex post liability to a firm's deep pocket financiers is efficient because the latter will induce the firms to adopt adequate prevention measures. The socially optimal level of prevention is then attained and victims are appropriately compensated if damage does occur. Reality, however, lags woefully behind such optimal conditions, as under asymmetric information, financiers have only incomplete information about the preventive measures adopted by the firms they finance. Thus, financial institutions cannot fully link the terms of the financial contract with the desired level of prevention. In such contexts, Boyer and Laffont (1997) show that partial extended liability may be necessary to obtain the second-best levels of financing and prevention.

Lenders' liability, insurance policies, and financial responsibility[12] are instruments through which responsibility is extended and therefore shared between the firms and their financial partners. Clearly, financiers will transfer their expected extended liability cost to the firm through the financing conditions: extending liability has an effect on a firm's prevention activities through the provisions surrounding the financing of the firm.

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be more common than expected or intended; for an economic analysis of lenders' liability cases, see Boyer and Laffont (1996), and Boyer and Porrini (2004).

[12] Financial responsibility may be proven by different means such as letters of credit and surety bonds; cash accounts and certificates of deposit; self-insurance and corporate guarantee. In the case of hazardous waste, the Resource Conservation and Recovery Act (RCRA) and the Comprehensive Environmental Response Act (CERCLA) provide for the companies that "treat, store, dispose, or transport hazardous waste" to demonstrate adequate financial guarantees for third-party damage, through an insurance or a proof of financial coverage. See also the Oil Pollution Act (33 USC §2716), the Safe Drinking Water Act (SDWA), the Outer Continental Shelf Lands Act (OCSLA), and the Surface Mining Control and Reclamation Act (SMCRA). See Boyd (2001) for an assessment of the implementation of financial assurance in the US: "On the whole, cost recovery, deterrence, and enforcement are significantly improved by the presence of existing assurance regulations."

Starting from the practical experience in the United States with CERCLA, any owner or operator of a facility involved in environmental damage may be held liable for clean-up costs and victims' compensation: in some court decisions[13] banks have been prosecuted in order to recover these costs, while others have been exempted, depending on their degree of implication in the activity of the firm, which made them, from the judges' point of view, either "operators of the facility" or not.

3. LIABILITY SHARING, COURT ERRORS, AND THE CHOICE OF ENVIRONMENTAL POLICIES

The economic analysis of the efficiency of lender's liability and financial responsibility[14] leads in the direction of characterizing the proper sharing of liability between firms and financiers. To allow for such considerations in our model, we give financiers the right to be protected from negligent firms, even under the basic strict liability rule: the financier may decide to sue the firm for negligence (that is, for having exerted a level of care lower than standard level fixed by the government) and if it does, it will fall on the courts to decide on negligence. The important role of the courts in this context is to assess and verify whether the firm did abide by the government-determined standard of care or not. In this way, the financial institutions have the possibility to recover part of the payment they already expensed (under strict liability) for the environmental damage caused by negligent firms.

But considering the role of the courts in judging the negligence of the firms, we come across the problem of the presence of judicial errors. That courts make errors is a fact, plainly accepted and studied by legal scholars. Regarding court errors, Tullock (1994) writes: "Even the best functioning legal system will not function without committing errors. Court errors can be about questions of law and questions of fact." Indeed in the U.S., state supreme courts used to be called "Court of Errors" because one of their main functions is to correct egregious errors by lower courts. Significant resources are devoted to improve, both from legal and fact-finding viewpoints, the record of courts at all levels in avoiding errors of Type I (finding an innocent firm guilty of negligence) and of Type II

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[13] See above footnote 10.
[14] About lenders' liability, see Pitchford (1995); about financial responsibility, see Fees and Hege (2000)

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(finding innocent a negligent firm). Marco (2006) quantifies beliefs about patent validity and court errors in a Bayesian context and estimates that market beliefs about courts show that Type I errors (finding a valid patent invalid) are believed to occur very frequently (45%) while Type II errors (finding an invalid patent valid), to occur with near zero probability.

In the law and economics literature, standard models of deterrence consider both types of errors and show that they are both detrimental to deterrence:[15] acquittals of guilty individuals make crime more profitable as they lower the probability of conviction and thus dilute deterrence, while convictions of innocents make crime more convenient by lowering the relative benefits of staying honest.

The theoretical consequences of court errors, particularly judicial errors and their reduction, i.e. the court system accuracy, have been analyzed in law and economics models on enforcement. As expressed by Kaplow (1994, p. 348): "Accuracy is relevant in controlling behavior because increasing accuracy, like increasing the level of sanctions or enforcement effort, is a method of increasing deterrence. The reasoning involves two components. First, greater accuracy- holding sanctions and enforcement effort constant- increases the likelihood that the guilty are sanctioned rather than mistakenly exonerated. Thus, individuals contemplating whether to act expect the likelihood of sanctions to be higher if they commit the harmful act. (The likelihood is the product of the probability that they will be detected and the probability that they will be sanctioned given detection. Increasing enforcement effort raises the first factor and increasing accuracy raises the second factor.) Second, greater accuracy reduces the likelihood that the truly innocent are sanctioned. This makes a decision not to commit the act look more attractive. Both factors -making harmful acts less attractive and harmless behavior more attractive- increase deterrence."[16]

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[15] See Png (1987); Polinsky and Shavell (2007).

[16] See Boyer, Lewis and Liu (2000) for a two stage game theoretic analysis where the level of enforcement effort and the level of negligence are simultaneously determined (in stage 2) in reaction to the levels of sanction and due care (stage 1) optimally chosen in anticipation of the second stage game played by the legal enforcer and the care exerting party.

Polinsky and Shavell (2007), among others, focus on the (negative) impact or such errors on deterrence. In their framework, accuracy is always desirable but reducing errors requires more enforcement resources and so a cost benefit analysis is needed to find the optimality. Bhole (2007) and Bhole and Wagner (2008) discuss different ways to induce a given care level through due-care standards and penalty multipliers when courts can err in finding firms guilty or not of improper behaviour.

Different results can be obtained depending on which liability framework is considered. For example, Bisso and Choi (2007), observing that a deep-pocket principal is often held liable and responsible for harm caused by a judgment-proof agent's negligence (vicarious liability). They analyse in such a context the relationships between a principal and an agent when a court determines whether the agent was negligent of not with some level of error. They show that "reducing the error of declaring the agent not negligent even when he was (pro-defendant or type II error) is better than reducing the error of declaring the agent negligent even when he was not (pro-plaintiff or type I error)." Intuitively, there is a mean preserving spread between the two in such a way that the agent is more sensitive to a reduction of the former.[17]

In our model, we consider a context where the courts impose liability on the injurer (agent) sued by a party (principal) that has some means to influence the injurer's choice of actions. This is an extended and shared liability framework. As discussed above, such a framework is often justified on the grounds that the agent tends to have insufficient assets to pay for the harm caused (judgment proof), hence suboptimal incentive to take care when performing a potentially hazardous task. From the viewpoint of environmental policies, extending liability to a deep-pocket principal will generate a reduction in the probability of accident because the principal is then induced to exert effort to influence the agent's chosen actions through better monitoring and a stronger incentive scheme for the agent. In our context, the law allows the principal to sue the agent if and when the latter causes an accident and is believed to have acted negligently. We consider the

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[17] See Rothchild and Stiglitz (1970) and Boyer and Dionne (1983) for discussions of mean preserving spreads.

interactions between the liability sharing factor and the efficiency of courts in avoiding judicial errors as determinants of the choice of environmental policies.

4. THE MODEL

The behaviours of the four actors, namely government, financiers, firms and courts, are subject to significant constraints: the limited liability of firms, the limited capacity of governments to intervene, the limited power of the court system to search and find all the facts relevant to a judgement, and the asymmetric information between the actors. The probability of an accident depends in a real sense on the actions of those four actors or stakeholders, interacting under information constraints, legal constraints, and bounded rationality constraints. It therefore results from the interactions between those actors, whose interests and objectives will not in general be congruent.[18] We analyse those interactions as a three stage game to characterize subgame perfect equilibria.

In stage 1, the government chooses the strict liability sharing rule α, by which the firm is strictly liable for α% of the cost of an accident while the financier is strictly liable for (1-α)% of that cost, and the standard level of care s to maximize a social welfare function we will characterize below.

In stage 2, given the values of α and s chosen by the government, a firm and a bank enter into a financial contract. We assume that the firm needs a loan of K from the bank to operate a risky project: the project generates net benefits (profits) π_1 with probability μ and π_2 with probability $1-\mu$, with $\pi_2 > \pi_1$. The realized level of profit is typically private information of the firm. The firm must repay the loan plus interest and failing to do so triggers bankruptcy procedures. In order to concentrate on the judgment proof problem, we assume that, in the no accident case, the firm always repays the bank and that, in the accident case, the bank has priority on other claimants on the firm resources. Hence, the loan is basically riskless.[19]

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[18] The model we develop here is based on Boyer and Porrini (2006, 2008) with an important change: the court assessment of liability in litigation cases.

[19] This is clearly a strong assumption which could be relaxed at the cost of more complexity. In the present case and for our purpose, this additional complexity would not bring significant additional insights.

The amount to be repaid by the firm to the financier depends neither on the firm's exerted level of care nor on the firm's profits, as those variable are unobservable; it is rather composed of two terms: $(1+r)K + (1-\alpha)p(s)L$, where r is the (exogenous) competitive riskless interest rate, and $(1-\alpha)p(s)L$ is a 'liability premium', where $p(\cdot)$ is the probability of accident and L is the level of damage if an accident occurs. This liability premium is based on the observed legal level of care s and not on the level of exerted care q.

The firm and the financier choose their respective decision variables at this stage: we assume that the financier first announces and commits to its choice of probability of suing v[20] at cost $C(v)$, before the firm, observing v, chooses a level of care activities q at cost $Q(q)$, which determines the true probability $p(q)$ of an accident [assumed to be decreasing and convex: $p'(q) < 0$, $p''(q) > 0$]. We characterize the resulting Stackelberg Equilibrium in (v, q).

Two different types of liability are present in our model: first, a strict liability rule that governs the share of costs that falls respectively on the financiers and the firms; second, a liability for negligence under which the financial partner can sue the firm to recover its share of the costs of the accident if the firm is found by the court to have exerted a level of care below the standard level determined by the government. It is through this capacity to sue that financiers appear as limited and constrained principals and the firms as agents.[21]

In stage 3, all actors observe whether an accident occurs or not (profits remain unobserved). If no accident occurs, the firm realizes the profits of the project and repays the bank. If an accident occurs, the strict liability rule applies: the financier is responsible

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[20] We assume that the financier commits to its choice of v. One may think that if the financier builds up a suing capacity, for instance through a specific inside group of lawyers, then it is bound to let them work full time and therefore sue firms with the implied probability v.

[21] See Shavell (1982) for the strict liability rule and Fagart and Fluet (2007) for the negligence rule. See also Demougin and Fluet (2008) for a discussion of the standard of proof in such a context. See also Boyer and Laffont (1996) and Boyer and Porrini (2004) for a discussion of the decision in the Fleet Factor case, in which the judge expands on the likelihood of financial partners to be better principals than government officials.

for covering (1-α)L and the firm for covering αL of the cost L of the accident. The financier sues the firm with probability v.

If the financier indeed sues the firm, then the latter incurs legal defence cost C_F and the case is litigated in court. The court suffers from asymmetric information, as the government and the financier, but is assumed to have superior power to investigate the safety behaviour of the firm. The court ponders the evidence and decides on whether there is breach of contract, that is, whether q is less than s or not. We represent the court decision making process under incomplete information as follows: the firm is found guilty of insufficient care with a reduced-form probability $\hat{P}(q,s) = f(q,s,\gamma)P(q,s)$, where the function $P(q,s)$ is assumed to be always positive (hence, both Type I and Type II errors are possible), but decreasing and convex in q and increasing in s [namely $P_q(q,s) < 0$, $P_{qq}(q,s) > 0$ and $P_s(q,s) > 0$]. The parameter γ in the function $f(q,s,\gamma)$ represents, as discussed below, the efficiency of the court in avoiding those errors: a larger γ will imply a lower probability of both Type I and Type II errors.

If convicted of negligence, the firm makes the additional payment $(1-\alpha)L$ if possible and otherwise goes bankrupt, in which case the financier seizes the firm's net assets, equal in value to $\max\{0, \pi_1 - \alpha L - ZZ - Q(q) - C_F\}$.

The determination of endogenous variables or decisions (α, s, v and q) is obtained recursively.

The third stage: At this stage all variables have been determined, leading eventually to a resulting state of the world. Hence, given previously determined values of α, s, v, and q, we obtain the expected values of the financier's profit and the firm's profit.

The total expected profit of the financier $E\Pi_I$ can be written as follows, where $ZZ = (1+r)K + (1-\alpha)p(s)L$:

$$E\Pi_I\left(v,q,\alpha,s;K,r,\pi_1,\pi_2,\mu\right) = ZZ - C(v)$$
$$- p(q)\left[(1-v)+v(1-\hat{P}(q,s))\right](1-\alpha)L$$
$$- p(q)v\hat{P}(q,s)(1-\mu)[0]$$
$$- p(q)v\hat{P}(q,s)\mu\left[(1-\alpha)L - \max\left\{0,\pi_1-\alpha L - ZZ - Q(q) - C_F\right\}\right]$$

The first term $ZZ - C(v)$ is the profit, gross of loan K, in the absence of an accident. If an accident occurs, then the financier will incur the full cost of its liability share, namely $(1-\alpha)L$, in two situations: first, if it does not sue the firm and second, if the firm is found not guilty by the court (second term: $-p(q)\left[(1-v)+v(1-\hat{P}(q,s))\right](1-\alpha)L$); if the financier sues the firm and the firm is found guilty, then the financier can recover its full share of the damages when the firm has realized the high level of profit, in which case the financier's cost is zero (third term: $-p(q)v\hat{P}(q,s)(1-\mu)[0]$, as we assume for simplicity that if profit is high, that is, if the project is ex-post very valuable, the firm can pay the full amount of damages; finally, if the financier sues the firm and the firm is found guilty, then it may be able to recover part of its (strict liability) payments if the firm has realized the low level of profit, in which case either the firm can pay part of the financier's costs or not, depending on whether $\pi_1 - \alpha L - ZZ - Q(q) - C_F$ is positive or not, hence the fourth term: $-p(q)v\hat{P}(q,s)\mu\left[(1-\alpha)L - \max\left\{0,\pi_1-\alpha L - ZZ - Q(q) - C_F\right\}\right]$.

The total expected profit of the firm $E\Pi_F$ can be written as follows, where $E\pi = \mu\pi_1 + (1-\mu)\pi_2$:

$$E\Pi_F\left(v,q,\alpha,s;K,r,\pi_1,\pi_2,\mu\right) = E\pi - Q(q) - ZZ$$
$$- p(q)(1-v)\left[(1-\mu)\alpha L + \mu\min\left\{\alpha L,\pi_1-Q(q)-ZZ\right\}\right]$$
$$- p(q)v(1-\hat{P}(q,s))\left[(1-\mu)(\alpha L + C_F) + \mu\min\left\{\alpha L + C_F,\pi_1-Q(q)-C_F-ZZ\right\}\right]$$
$$- p(q)v\hat{P}(q,s)\left[(1-\mu)(L+C_F) + \mu\max\left\{0,\pi_1-Q(q)-C_F-ZZ\right\}\right]$$

In light of our interpretation of the different terms of the expected profit of the financier, each term of the above expression is self explanatory.

The second stage: At this stage, the values of values of α and s have been determined and the firm and the financier choose their respective decisions. The firm chooses q satisfying

$$\frac{\partial E\Pi_F}{\partial q} = 0$$

giving rise to the best reply function $q(v \mid \alpha, s; \gamma, K, r, \pi_1, \pi_2, \mu, L, C_F, C_B)$ to the choice of v made by the financier, given α and s set by the government. Knowing this best reply function of the firm, the financier chooses v satisfying

$$\frac{dE\Pi_B}{dv} = 0$$

taking full account of the best reply function of the firm. The solution to these two conditions gives us the second stage *equilibrium* values, which can be expressed as functions of the government-determined variables α and s, namely:

$$v^*\left(\alpha, s; \gamma, K, r, \pi_1, \pi_2, \mu, L, C_F, C_B\right)$$

$$q^*\left(\alpha, s; \gamma, K, r, \pi_1, \pi_2, \mu, L, C_F, C_B\right).$$

The first stage

We consider, again to simplify the presentation but without loss of generality, that the determination of the liability sharing formula involves a "political economy" cost $A(\alpha)$ if the government wants to implement a formula away from the most acceptable formula from a social or political standpoint (assumed below to correspond to an equal liability sharing: α=50 %).[22]

The social welfare function $SWF(\alpha, s)$ is given by the following, where W is the social value of the firm's project or activities and λ is the social cost of public funds representing the cost of government financing either through taxation or public debt:

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[22] This assumption will make the interpretation of the chosen α easier by determining a reference point α=50%. It plays no other role.

$$SWF(\alpha,s) = [W - p(q^*)L - Q(q^*) - C(v^*) - A(\alpha)]$$
$$- \lambda p(q^*)(1-v^*)\mu \max\{0, \alpha L - (\pi_1 - ZZ - Q(q^*))\}$$
$$- \lambda p(q^*)v^*\left(1 - \hat{P}(q^*,s)\right)\mu \max\{0, \alpha L - (\pi_1 - ZZ - C_F - Q(q^*))\}$$
$$- \lambda p(q^*)v^*\hat{P}(q^*,s)\mu \max\{0, \alpha L - \max\{0, \pi_1 - ZZ - C_F - Q(q^*)\}\}$$

The first term of the *SWF* function, $[W - p(q^*)L - Q(q^*) - C(v^*) - A(\alpha)]$, is simply the net value of the firm/project absent an accident: the social value W minus the expected cost of an accident, the cost of care, the cost of maintaining the legal suing capacity, and the political economy cost of moving away from the most acceptable liability sharing formula.

The second term, namely $-\lambda p(q^*)(1-v^*)\mu \max\{0, \alpha L - (\pi_1 - ZZ - Q(q^*))\}$, represents in expected terms the social cost of payments by the government if an accident occurs and the financier is not suing the firm. The firm may be unable to pay its own share of the damages, in which case the government must one way or another pay for the remaining damages, clean-up costs or compensation costs.

The third term, namely $-\lambda p(q^*)v^*\left(1 - \hat{P}(q^*,s)\right)\mu \max\{0, \alpha L - (\pi_1 - ZZ - C_F - Q(q^*))\}$, represents in expected terms the social cost of payments by the government if an accident occurs, the financier is suing the firm (the firm then suffers a legal defence cost C_F), and the firm is found not guilty. The firm may again be unable to pay its share of the damages of the accident.

Finally, the fourth term, $-\lambda p(q^*)v^*\hat{P}(q^*,s)\mu \max\{0, \alpha L - \max\{0, \pi_1 - ZZ - C_F - Q(q^*)\}\}$, represents in expected terms the social cost of disbursements by the government if an accident occurs, the financier is suing the firm, and the firm is found guilty of negligence. The firm may once again be unable to pay the full damages of the accident. To understand the form of this last term, one must realize that the government will be a payer only if the firm cannot even repay its own share of the damages, in which case the firm cannot reimburse the financier and the government will pay the residual value

$\alpha L - \{\pi_1 - ZZ - C_F - Q(q^*)\}$. However, if the firm can reimburse a part of the financier's cost when found guilty of negligence, that is $\alpha L - \max\{0, \pi_1 - ZZ - C_F - Q(q^*)\} < 0$, then the government would pay nothing under the rule of strict liability of the firm and the financier.

The government maximizes this *SWF* function with respect to α and *s*, considering the social cost of public funds and the effect of its decision on the choice of *v* and *q* in the second stage and the resulting probability of accident, expected damages, the court efficiency in avoiding errors, and the total costs of realizing the project, that is, of allowing the firm to operate.

Clearly, the general solution of such a program and the full characterization of the three-stage equilibrium is a formidable task. Rather than deriving such a general characterization, which at best will be seriously restricted by a set of conditional statements, we will consider a simplified example, which represents or includes the relevant characteristics of the problem at hand.

5. A SIMPLIFIED EXAMPLE

We consider the following functions that satisfy the general characteristics of the functions we introduced above.

$$p(q) \equiv p_0 + (p_M - p_0)(1 - e^{-\eta q}) \begin{cases} = p_0 & \text{if } q = 0 \\ \to p_M > 0 & \text{if } q \text{ becomes very large} \end{cases} \tag{1}$$

$$\hat{P}(q,s) \equiv (-\gamma q^2 + \gamma sq + 1)e^{-\delta(q/s)}$$
$$\begin{cases} = 1, & \text{if } q = 0 \\ = e^{-\delta}, & \text{if } q = s \ \left(\hat{P}(s,s) = 0.5 \text{ if } \delta = \ln 2\right) \\ \to 0, & \text{as } q \text{ becomes very large} \end{cases} \tag{2}$$

where $(-\gamma q^2 + \gamma sq + 1)$ equals 1 if either $\gamma = 0$ or $q = s$, is increasing with γ if $q < s$, and is decreasing with γ if $q > s$. Hence as γ increases, the probability of finding the firm

guilty increases if $q < s$, hence a reduction in Type II errors, and decreases if $q > s$, hence a reduction in Type I errors.

$$Q(q) \equiv zq^b \text{, where } b > 1 \text{ and } z \text{ is a positive parameter.} \tag{3}$$

$$C(\nu) \equiv B\nu^n \tag{4}$$

$$A(\alpha) \equiv A(\alpha - 0.5)^a \tag{5}$$

We consider the following base case parameter values: $\pi_1 = 1000$, $\pi_2 = 5000$, $\mu = 0.2$,

$K = 75$, $r = 0.10$, $p_0 = 0.4$, $p_M = 0.05$, $\delta = \ln(2)$, $z = 10$, $b = 1.2$, $L = 4000$, $\eta = 0.2$,

$C_F = 0$, $B = 1$, $n = 2$, $\lambda = 0.3$, $A = 25$, $a = 2$, and $\gamma = 0$.

Given those values, we obtain the following first-best solution:[23]

$$\alpha_{FB} = 0.5, \; q_{FB} = s = 13.17, \; p(q_{FB}) = 0.075 \, ;$$

and the following asymmetric information solution, which is our base case scenario, from which sensitivity analysis will be performed in the next section.

Base Case

Table 1: Base case scenario

α	s	υ	q	$p(q)$	$\hat{P}\,(q,\,s)$
0.37	17.336	0.895	11.902	0.082	0.621

Hence, in this equilibrium with asymmetric information, we have $\alpha < \alpha_{FB}$, that is, the liability share of the firm is lower than in the first-best (complete, although imperfect

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information) solution. Moreover, $q < q_{FB} = s$ and $p(q) > p(q_{FB})$, that is, the firm exerts less care in preventing accident and therefore the probability of accident is larger than under first-best conditions.

6. SENSITIVITY ANALYSIS

We consider in this section the impact on the first-best and second-best liability sharing α, standard of care s, probability of suing υ, exerted care level q, probability of accident $p(q)$, and probability of conviction if sued $\hat{P}(q,s)$, of changes in the profitability of the firm's project or activities (μ), the cost (z) of care activities, the efficiency (η) of care in reducing the probability of accident, the cost of suing (B), the social cost of public funds (λ), and the court efficiency (γ) in avoiding errors. In the following tables, the bold line corresponds to the Base Case scenario of Table 1.

Case 2: Sensitivity to changes in the profitability of the firm

The parameters are same as in the above Base Case 1 except for the parameter representing the profitability of the firm, namely $\mu \in [0.1,\ 0.3]$; as μ increases, that is, as the probability of a low level of profit increases, the profitability of the firm's project or activities decreases. We obtain the following:

Table 2: variable μ (profitability)

μ	α	s	υ	q	$p(q)$	$\hat{P}(q, s)$
0.10	0.648	7.816	0.819	12.104	0.081	0.342
0.15	0.494	12.747	0.876	12.043	0.081	0.520
0.20	**0.374**	**17.336**	**0.895**	**11.902**	**0.082**	**0.621**
0.25	0.256	22.841	0.906	11.721	0.084	0.701
0.30	0.183	26.872	0.910	11.495	0.085	0.743

Hence, a reduction in the profitability of the firm (higher μ) generates a reduced liability for the firm and an increased standard of care; an increase in the probability of suing; a reduction in the level of care and a rise in the probability of accident; and a rise in the probability of conviction. The main factor explaining those results is that a lower profitability of the firm implies a more frequent reliance on government funds to cover the cost of an accident. Hence, to alleviate the effect of the social cost of public funds on the value of SWF, the financier is made increasingly liable, that is, the legal compulsory level of insurance for environmental disasters is increased. Although the level of suing increases, the firm tends to lower its care activities given its reduced liability. The increases in s combined with the reduction in q increases the probability of conviction.

Case 3: Sensitivity to changes in the cost of care

The parameters are same as in Base Case 1 except for the parameter representing the cost of care activities, namely $z \in [5,\ 20]$. We obtain the following, where the first-best solution changes with the changes in parameter z:

Table 3: variable z (cost of care)

$z \quad [\alpha_{FB,}\ q_{FB,}\ p_{FB}]$	α	s	υ	q	$p(q)$	$\hat{P}\ (q,\ s)$
5.00 [0.5, 16.417, 0.063]	0.403	12.791	0.882	15.038	0.067	0.443
7.50 [0.5, 14.513, 0.069]	0.391	15.438	0.890	13.202	0.075	0.553
10.0 [0.5, 13.171, 0.075]	**0.374**	**17.336**	**0.895**	**11.902**	**0.082**	**0.621**
12.5 [0.5, 12.137, 0.081]	0.346	19.141	0.900	10.906	0.090	0.674
15.0 [0.5, 11.298, 0.087]	0.320	20.045	0.903	10.089	0.097	0.705
17.5 [0.5, 10.591, 0.092]	0.302	19.547	0.903	9.392	0.103	0.717
20.0 [0.5, 9.983, 0.098]	0.267	19.865	0.906	8.803	0.110	0.736

Hence, a higher cost of care changes the first-best values (a reduced care q and therefore an increased probability of accident $p(q)$) and generates: a reduced liability for the firm

but the standard of care goes up and down; an increase in the probability of suing; a reduction in the level of care; a rise in the probability of accident and in the probability of conviction. The fact that the first-best level of care is reduced implies that the government wants to set a lower liability share for the firm inducing a lower level of care and therefore a higher probability of accident.

Case 4: Sensitivity to changes in the efficiency of care

The parameters are the same as in Base Case 1 except for the parameter representing the efficiency of care in reducing the probability of accident, namely $\eta \in [0.1, \ 0.3]$. We obtain the following, where the first-best solution changes with the changes in parameter η:

Table 4: variable η (efficiency of care)

$\eta \quad [\alpha_{FB}, \ q_{FB}, \ p_{FB}]$	α	s	υ	q	$p(q)$	$\hat{P}(q, s)$
0.10 [0.50, 18.709, 0.104]	0.318	44.440	0.938	16.697	0.116	0.771
0.15 [0.50, 15.433, 0.085]	0.366	27.524	0.917	13.918	0.093	0.704
0.20 [0.50, 13.171, 0.075]	**0.374**	**17.336**	**0.895**	**11.902**	**0.082**	**0.621**
0.25 [0.50, 11.536, 0.070]	0.362	12.448	0.874	10.428	0.076	0.560
0.30 [0.50, 10.297, 0.066]	0.358	9.206	0.849	9.286	0.072	0.497

Hence, an increased efficiency of care in reducing the probability of an accident changes the first-best values (reduced care level q and a reduced probability of accident $p(q)$) and generates: a liability for the firm that goes up and down but a decreased standard of care; a reduction in the probability of suing; a reduction in the level of care but a reduction in the probability of accident; and a reduction in the probability of conviction. When care is more efficient, the government wants to save on costly care activities while achieving a lower probability of accident. To do so, it basically maintains the liability share of the firm but reduces the standard of care; this lowers the value of suing for the financier.

Although realized care level and probability of accident move in the same directions as their first best values, the probability of conviction goes down as the reduction in realized care is less pronounced than the reduction in the standard of care.

Case 5: Sensitivity to changes in the cost of suing (efficiency of monitoring)

The parameters are the same as in Base Case 1 except for the parameter representing the cost for the financier of suing, that is, the cost of maintaining the necessary internal legal competencies, namely $B \in [0.5,\ 2.5]$. We obtain the following:

Table 5: variable B (cost of suing)

B	α	s	υ	q	$p(q)$	$\hat{P}\ (q,\ s)$
0.50	0.303	24.167	0.935	12.078	0.081	0.707
1.00	**0.374**	**17.336**	**0.895**	**11.902**	**0.082**	**0.621**
1.50	0.432	14.016	0.856	11.765	0.083	0.559
2.00	0.492	11.554	0.812	11.645	0.084	0.497
2.50	0.564	9.314	0.751	11.535	0.085	0.424

Hence, an increase in the cost of suing generates: an increased liability for the firm and decreased standard of care; a reduction in probability of suing; a reduction in the level of care; an increase in the probability of accident; and, a reduction in the probability of conviction. Clearly, the capacity or efficiency of the financier in inducing proper behavior by the firm is reduced when the cost of suing increases. Hence, the government will want to impose a higher liability share on the firm. To avoid a too important increase in care activities, it lowers significantly the standard of care leading to a net decrease in the level of care. But again, the reduction in realized care is less pronounced than the reduction in the standard of care and therefore the probability of conviction is lowered.

Case 6: Sensitivity to changes in the social cost of public funds

The parameters are same as in Base Case 1 except for the parameter representing the social cost of public funds, namely $\lambda \in [0.1,\ 0.5]$. We obtain the following:

Table 6: variable λ (social cost of public funds)

λ	α	s	υ	q	$p(q)$	$\hat{P}(q, s)$
0.1	0.768	7.698	0.761	11.907	0.082	0.342
0.2	0.533	14.157	0.871	11.921	0.082	0.558
0.3	**0.374**	**17.336**	**0.895**	**11.902**	**0.082**	**0.621**
0.4	0.220	20.056	0.909	11.883	0.083	0.663
0.5	0.181	20.769	0.912	11.879	0.083	0.673

Hence, an increase in the social cost of public funds (reduced efficiency of government financing) generates: a reduced liability for the firm and increased standard of care; an increase in probability of suing; an early increase and later reduction in care; an early reduction and later increase in probability of accident, the precise values being 0.082345, 0.082258, 0.082377 (the base case value), 0.082503, and 0.082528; and, an increase in the probability of conviction. Those impacts are basically due to the need for the government to reduce its own disbursements given their higher social costs. To achieve that, it lowers the liability share of the firm thereby making the compulsory insurance level higher. To avoid a too important reduction in care, the government increases also the standard of care. This induces the financier to sue more often because of the higher probability of conviction.

Case 7: Sensitivity to changes in the efficiency of the court system

The parameters are the same as in Base Case 1 except for the parameter representing the efficiency of the court system to avoid errors of Type I and II, namely $\gamma \in [0,0.009]$. We obtain the following:

Table 7: variable γ (efficiency of the court system)

γ	α	s	υ	q	$p(q)$	$\hat{P}$ (q, s)
0.000	**0.374**	**17.336**	**0.894**	**11.900**	**0.082**	**0,621**
0.001	0.400	15.0580	0.889	12.108	0.081	0,593
0.002	0.341	14.2430	0.892	12.314	0.080	0,575
0.003	0.304	13.2460	0.891	12.480	0.079	0,535
0.004	0.281	12.3610	0.888	12.602	0.078	0,487
0.005	0.265	11.6440	0.883	12.693	0.078	0,438
0.006	0.249	11.1070	0.877	12.775	0.077	0,393
0.007	0.235	10.6730	0.871	12.842	0.077	0,350
0.008	0.223	10.3310	0.864	12.903	0.077	0,309
0.009	0.211	10.0630	0.856	12.961	0.076	0,271

As parameter γ increases, the efficiency of the court system in avoiding errors of Type I and II increases as increases in γ increases the probability of conviction $\hat{P}$ (q, s) if $q < s$, that is, when insufficient care is exerted by the firm, and reduces that probability if $q > s$, that is, when more than sufficient care is exerted. Hence, an increase in the efficiency of the court system generates: a reduced liability for the firm (for $\gamma \geq 0.001$) and a reduced standard of care; a decrease in probability of suing (for $\gamma \geq 0.002$); an increase in the level of care exerted by the firm, from below the standard level chosen by the government to above that value for $\gamma \geq 0.004$; a corresponding reduction in the probability of accident;[24] and, a reduction in the probability of conviction, which blends different factors, namely the higher efficiency of the court system, the reduction in the standard of care, and the increase in the level of care exerted.

[24] The probability decreases steadily even if some values in Table 7 are the same due to rounding values.

From the results reported in Table 7, we can say that the efficiency of the court system to avoid errors of both Type I and Type II improves the efficiency of liability sharing as an environmental policy instrument: an increase in γ generates a decrease in the probability of accident $p(q)$) resulting from the new liability sharing factor and the new decisions by financiers and firms.

Two observations of the impact of an increase in the efficiency of the court system deserve some comments. First, as γ increases, firms tend to exert an "excessive" level of care q as compared to the due care level s chosen by the government. Second, this increase in γ allows the government to reduce the liability share of firms at the expense of a larger liability share of financiers.

Regarding the first effect, it suggests that the increased efficiency of the court system generates stronger incentives for firms to exert more care, eventually surpassing the due care level.[25] Moreover, this increased efficiency of the court system means that firms, which may also suffer from the fact that their chosen care level is difficult to observe, would indeed increase their level of care if it can be recognized with more accuracy by the courts if and when an accident occurs and the firm is sued by its financial partner. We observe in reality many forms of self regulation (like cases of green certification) that show an effort by the firms to exert care that goes beyond the legal standard. Such self regulation may also serve to convey to financiers better assurance that a given firm will exert a higher level of care, once the government increases the share of liability falling on financiers increases as the efficiency of the court system increases.

Regarding the second effect, it implies that the increased efficiency of the court allows the government to increase the liability share of financiers. Two reasons justify this policy choice: first, if the firms behave negligently there will be a credible way for financiers to partly recover their share of the costs of an environmental accident and second, the government, given the social cost of public funds, wants to avoid costly disbursements by transferring liability from firms to financiers.

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[25] See the discussion of Kaplow (1994) and the others in Section 3 above.

From an environmental protection viewpoint, the legislator can transfer more liability to financiers if it can provide a more efficient justice system, thereby protecting financiers against the negligent behavior of firms: investing in the justice system to increase the efficiency of courts to avoid errors generates benefits for the government both in terms of reductions in accident probabilities and in terms of public money disbursements given that the strict liability of financiers for environmental accidents can be increased.

7. CONCLUSION

The different impacts of a more efficient court system on liability sharing and environmental protection are due to intricate interactions between the different factors shaping the incentives faced by firms in their safety care strategies as well as the social welfare maximizing objective of the government. When facing a more efficient court system, which contributes to raising the incentives of firms to exert more care, the government chooses to enact legislation providing a lower legal liability share for the firms as well as a lower standard level of care, expecting that firms and financiers will exploit such legal provisions to reduce the probability of suing and to increase the level of care, resulting in the end in a reduced probability of accident. Hence, a more efficient court system allows the stakeholders to face better incentives allowing for a reduction in the probability of suing and a reduction of the likelihood of costly government disbursements due to a lower liability share for firms, a reduced probability of accident, as well as a reduced overall probability of conviction if an accident case is litigated in courts.

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