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Risky Activities and Strict Liability Rules: Delegating Safety

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JEL Classification: K0, K32, Q01, Q58

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0. Introduction

In April 2010, the BP's offshore drilling rig explosion spilled crude oil in the Mexico Gulf and polluted it on a large scale. This event reminded us that our contemporaneous industrial societies are highly sensitive to technological hazards. Indeed, productive activities generate potential huge harm with large ripple effects on public health or natural resources. Governments and corporate managers of risky activities have to find effective tradeoffs between natural resources preservation and economic growth.

From an economic viewpoint, industrial accident are negative externalities that disturb the classical adverse selection problem of "*no distortion of the top*" put into evidence in the eighties by Maskin and Riley (1984), (Baron and Myerson (1982)), (Mussa and Rosen, 1978), (Myerson, 1981). These disruptions involve that the most efficient agent cannot get the first-best outcome. The range of *ex-ante* and *ex-post* environmental regulatory instrument defined to overcome this problem is quite wide (see for instance (Kolstad, Uhlen and Johnson, 1991), (Schmitz, 2000)). Strict liability regimes are legal instruments usually implemented to protect the environment with twofold objectives: compensating damage and inducing managers to take preventive measures. Strict liability regimes share the same feature in the sense that the proof of any fault is unnecessary to compensate victims. Hence, liability is implied by the mere existence of a causal link between the risky activity and the harm, this, regardless of the level of care the liable agent exercised beforehand. Strict liability means that he must repair the entire damage he caused. Undoubtedly, this regime advantages victims that can access rapidly to compensation without bearing the burden of the proof. However, its main weakness is that redresses amount can exceed the polluter's financial capacities and lead him to become judgment proof (Summers, 1983), (Shavell, 1986)). Hence, Society as a whole will endure the cost of the incomplete internalization process.

In spite of this flaw, the present paper revisits the strict liability question. It considers, paradoxically, that putting ceilings to the total amount of repairs can induce efficient agent to offer a first best prevention effort.

More precisely, this contribution compares the relative performance of two civil strict liability regimes: "standard" strict liability and "capped" one. Under a "standard" strict liability scheme, the liable agent must repair the damage in its totality (as, for instance, in the

CERCLA[1] scheme or the Environmental liability directive of the EU of 2004[2], (OECD 2009)). Economics literature calls this case "limited" liability because of the judgment-proof risk (Jost, 1996), (Segerson and Tietenberg, 1992.). In the opposite, the Law puts ceiling on the level of repairs in the so-called "capped" strict liability regimes (as in the maritime sector for oil pollution or in the electro-nuclear industry). This is also a limited liability case but polluters' financial resources are preserved.

To deal with the judgment-proof question two options may be considered. The main one shifts the liability burden to vicarious or solvent third parties. Following Shavell (1986), authors as Pitchford (1995), Boyer and Laffont (1997) or still Heyes (1996) initiated a huge literature that studies vicarious liability under ex-post liability rules. Recently, Hiriart and Martimort (2006)) opened this field to criminal liability by combining fines and rewards. Boyer and Porrini (2006) (2008) explore the relationships of banks and firms under tort law where the decision of the court is random.

Without contesting these views, the present paper explores the much less crowded second option. Boyd and Ingberman (1994), Dari-Mattiacci (2006) extend the Beard (1991)'s contribution to cap strict liability. They show that capping the repairs amount may induce firms to increase their prevention effort and, then, contribute to improve the social welfare that standard strict liability struggles to meet. Basically, our model assumes double asymmetric information: first, the efficiency in providing safety and, second, the level of wealth between the principal and the agent. Capping strict liability induces the efficient agents to supply the first best solution of the symmetric information under standard strict liability and, this, at the price of a minimized informational rent.

A first paragraph presents some examples of sectors ruled by capped strict liability. These are mainly the maritime and the electro-nuclear sectors. We will discuss there much more analytically the previous contributions. In a second paragraph, the basic features of the model are given. The first rank level of safety effort under symmetric information for standard strict liability regime is defined. A third paragraph shows that information asymmetry breaks this scheme because efficient agents are deterred to accept the delegation. In a fourth

[1] Since the early 80's, the US Congress enacted the *Comprehensive Environmental Response, Compensation and Liability Act* (CERCLA) and created a *Superfund* for cleaning-up dangerous waste sites, (see Roman (2008)).

[2] 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).

paragraph, capped liability is introduced and we study how first rank level of effort is supplied by the most efficient agent. A fifth paragraph concludes.

1. Some considerations about the institutional capping of strict liability

Both the maritime sector and the electro-nuclear industry are regulated by strict liability regimes. The International Convention on Liability and Compensation for Bunker Oil Pollution Damage of 2001 states the strict liability of ship-owners for all types of pollution damage caused by bunker oil. However, this liability is subject to the limits of applicable national or international regimes not exceeding an amount calculated in accordance with the amended 1976 Convention on Limitation of Liability for Maritime Claims. Concerning the maritime transport, compensation for oil pollution is regulated by the International Convention on Civil Liability for Oil Pollution (CLC) and the International Convention setting up. The Oil Pollution Compensation Fund (Fund Convention) establishes a two-tier liability system built upon the (limited) strict liability for the ship owner and a collectively financed fund which provides supplementary compensation to victims of oil pollution damage who have not obtained full compensation. This notion of full compensation does not apply to the environment as a whole, but to people privately concerned by personal losses in a civil strict liability regulation context.

After the Exxon Valdez disaster, the USA adopted the 1990 Oil Pollution Liability and Compensation Act. It states the ability to collect from companies for natural-resource damage and gives victims the right to make claims directly to the company. All claims for damages made under the 1990 act are capped at $75 million. The law also set up a trust fund to pay claims companies involved in oil spills decline to pay. However, after the Deepwater Horizon rig explosion, obviously, this fund revealed to be too low and Democrat senators are proposing to raise the cap to $10 billion in the wake of the BP spill with a retroactive effect. Nowadays, the point is still at stake.

The nuclear civil liability is essentially ruled by international conventions[3]. They establish a strict liability regime channeled exclusively to the operators of the nuclear

[3] IAEA's Vienna Convention of 1963, OECE's Paris Convention on Third Party Liability in the Field of Nuclear Energy of 1960 and the Convention on Supplementary Compensation for Nuclear Damage (CSC) of 1997 amended in 2003 and the OECD Paris (and Brussels) Conventions Amending Protocols of 2004.

installations. If this liability is absolute, it is limited in time and amount which is set to €1.500M (see World Nuclear Association 2009).

Hence, the liable agent is exposed to a level of redress substantially lower than the amount of the harm. This lightened responsibility should act as an investment incentive for firms. For instance, developing nuclear industry involves relieving nuclear operators of the burden of potentially ruinous liability claims[4]. However, under the ceiling of repairs, the internalization process remains structurally incomplete because the victims' rights to full compensation[5] are seriously impaired. Let us note that capped strict liability does not preclude individuals from making other claims (civil claims that the company was negligence or malfeasant).

Some authors consider that this regime induces operators to lower their safety effort (Faure and Hu, 2006), (Faure and Wang, 2008)) because they proportionate it to the level of redress. At a political level, this analysis is echoed by opponents to the introduction of such liability regimes[6]. However, some authors consider that limiting the amount of the polluters' repair may induce them to increase the safety level beyond an optimal level, (Beard 1990), (Miceli and Segerson, 2003), (Dari-Mattiacci, 2006). For instance, this author insists on the tradeoff between the cost of precaution and the amount of wealth dedicated to redress. The liability caps are independent from the injurer's safety expenditures that can contribute to limit excessive precaution and reduce the insolvency risk. Hence, a potential insolvent agent may be induced to take too much precaution compared to the social optimum. This increases the total social costs of accident: the more is spent on prevention, the less for repairs. Bounding the liability allows the injurers to spare more for compensation (Dari-Mattiacci, 2006). When they consider the social optimum, these articles do not take into consideration potential victims and limit it to the polluter's welfare. In the present paper, potential victims are considered through the principal that acts as their representative. Hence, the question of

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[4] More explicit still is The "*Exposé des Motifs"* for the 1960 Paris Convention that considers that "unlimited liability could easily lead to the ruin of the operator without affording any substantial contribution to compensation for the damage caused" (*Exposé des Motifs*, Motif 45) or still (Schwartz, 2006:39)

[5] See for instance (Boyd 2001, p.47):" *On the other hand, these benefits to regulated industries must be weighed against the obvious drawback of capped liability: namely, that environmental costs above the cap will be uncompensated by responsible parties*."

[6] In India, for instance, the Coalition for Nuclear Disarmament and Peace (CNDP), in its Appeal against the Proposed Civil Nuclear Liability [Cap] Bill ask the Indian government to increase the level safety considering the choice for the nuclear energy industry. In http://www.sacw.net/article1288.html. See also (Anderson and Ahmed, 1996).

the “under investment” or the “over-investment” in safety does not arise in the same terms. In the opposite, in the following we show that this kind of regime can improve the situation of both agents and the representative of the Society (The principal).

2. Economic environment: technology, preferences, information

This paper borrows the methodology of asymmetric information theory. However, basically, it rests on the foundations of liability theory developed by Shavell (1986). Indeed, we consider that agents focus on safety level mainly. That means that reference to the quantity supply question is only implicit. Indeed, we consider that agents differ only by the marginal costs of their safety effort. That means that regarding quantities, the principal considers that the marginal production costs of gross production are almost identical. Putting it otherwise, production technologies are roughly similar but differ mainly by the level of care brought by the agent. Hence, the RA knows that agents compete about safety which is reflected in differentiated marginal costs. This state of matter is a common feature considering most modern products and production because knowledge about basic technology is available everywhere. For instance, if cars have similar basic structure, however, brands differ in their specific embedded equipment about safety or quality (see for instance, (Gabszewicz, and Thisse,1979), (Tirole,1988, chap.7), (Tay 2003), (Toshimitsu and Jinji, 2007). Every Nation knows how to produce basic cars, but only few among them can control safety equipments. This observation extends for most goods or services as, for instance, nuclear power plants or delegated water services. Nowadays, for most products and production, competition bears more on quality than on the question of quantity.

Consequently, in order to assess a relevant level of transfers to pay for safety (as an embedded part of the total price) the principal has to observe the level of care effort. Let us explain the point. Most of risky activities are under the supervision of authorities or State Agencies. They give permits and administrative authorizations to operators that deal with dangerous activities (chemical plants, electro-nuclear production, waste treatment, etc.). That involves that the quality and the safety of the products have to be checked up regularly. For instance, regular inspections may verify the safety of facilities, the existence of installations etc. This may be assimilated to the checking of the level of the safety effort e. However, the Principal or the RA cannot appreciate the effective efficiency of the agent when managing this effort. For instance, the Deepwater Horizon rig explosion causing the Gulf of Mexico oil spill, had suffered a leak in the weeks leading up to the blast. This leak has been insufficiently appreciated by the BP's management. Tad Patzek (2010) considers that the problem is deeper than a simple monitoring question and involves the necessary revision of the whole production structure. Difference in marginal costs in safety indicates the degree of skill of the agent and this is private information. Let us come again to the question of cars. Everybody can compare and even check the set of safety equipments from a brand to another one and can accept to pay more or less according the sophistication degree of a model. However, it is difficult to appreciate the effective producer's skill for a specific car model. This is the root of asymmetric information in our model. Hence, if the principal can accede to the level of agents' safety effort, he cannot appreciate their effective skill. The more efficient an agent is, the lowest his safety marginal costs.

2.1 General feature of the model

A Regulatory Agency (RA) or Principal wants to delegate to the private sector the production of a public good. This activity can induce severe harm to the Environment and/or public Health. Besides the product, the RA needs also an optimal safety level (for instance good water quality or safe electro-nuclear power, or still good conditions for oil transportation.). The Principal derives a benefit $S(e)$ from the acquisition of the good provided that it ensures an adequate level of security e. $S(e)$ is defined on $\mathbb{R}$ with $S'_e > 0$ and $S''_{ee} > 0$. Furthermore, this function satisfies the Inada condition: $S'(0) \to +\infty$ and $\lim_{e\to 0} S'(e)\, e = 0$.

We will analyze respectively both regimes the strict liability one and the capped one. The last one puts ceilings of the level of repairs. Let y be the level of the agent's wealth, and D the level of damage (where $y < D$) if major accident occurs. Hence, the damage costs exceed the agent's financial capacities. Under a standard liability regime, if a benevolent Court considers the agent as liable, he will have to pay on his own assets. However, if his wealth is insufficient for full repairs, he becomes judgment proof (Summers, 1983), (Shavell, 1986)). Under a capped liability scheme, the amount of damage is fixed to C, where $C < D$ and liable agents escape the judgment-proof situation. The potential damage D of the activity is common knowledge as the probability distribution of the environmental harm $p(e)$ where $p'_e < 0$ and $p''_{ee} > 0$.

Informational asymmetries are two: i) the level of safety effort and ii) the agent's wealth that cannot be considered as public information. Compared to models that deals with liability and competition, as (Pitchford, 1995), (Laffont and Boyer (1997), (Boyd and Ingerman, 1997), (Hiriart and Martimort, 2006), we dissociate the level of safety effort from the efficiency about the skill of the firm in its management of safety.

2.1.1 *The utility functions of the RA and the Agent*

When the RA acquires the public good, he requires also a given level of safety and the RA's utility function is:

$$V = S(e) - t \qquad [1]$$

Where, t is the payment made to the agent by the RA, t has to be high enough to cover the costs induced by the production activity and the safety effort. If U is the profit function of the agent:

$$U = t - C(e, K) \qquad [2]$$

This writing means that the agent assesses both cost of safety and he has to internalize the possible damage to the environment $Kp(e)$ where $K = \{C, y\}$ is the amount of the redress under a capped strict liability regime for a fixed amount C and a y (the amount of his wealth) for a "standard" strict liability. The value θ stands for the marginal cost of safety efforts made by the agent where $\theta \in \{\overline{\theta}, \underline{\theta}\}$ with $\underline{\theta}$ (respectively $\overline{\theta}$) the marginal safety effort cost of the efficient (resp. inefficient) agent). As agent's efficiency is private information, the RA assesses the following probability distribution on the distribution between efficient agent (ϑ) and inefficient ones $(1 - \vartheta)$, $(1 \geq \vartheta \geq 0)$.

We can define the firm's cost function considering the possibility of the occurrence of a severe accident (probability $p(e)$). The expected cost of safety writes now:

$$C(\theta, e, K) = \theta e \left(1 - p(e)\right) + (\theta e + K)p(e) \qquad [3]$$

Or, after developing:

$$C(\theta, e, K) = \theta e + K\, p(e) \qquad [4]$$

For $\theta \in [\overline{\theta}, \underline{\theta}]$ and $K = \{C, y\}$

And the profit function becomes:

$$U = t - C(\theta, e, K) = t - \theta e - Kp(e) \qquad [5]$$

We deduce the society's welfare function:

$$W = \mathrm{U} + \mathrm{V} = S(e) - \theta e - p(e)D \text{ for } \theta \in [\overline{\theta}, \underline{\theta}]^{7} \qquad [6]$$

[7] See appendix

We can notice that this function is such that $W'(e) > 0, and\ W"(e) > 0$, this because$S'(e) > 0, D > 0\ and\ p'(e) > 0$. As for standard asymmetric information theory we can define the contracting outcome: the relevant variables are the level of effort e necessary to achieve an acceptable level of safety and the transfer t received by the agentt. Let Ξ the set of feasible allocations that is given by:

$$\Xi = \{(e, t): e \in \mathbb{R}_{+,} t \in \mathbb{R}_{,}\}$$

These variables are both observable and verifiable by a third party such as a benevolent court of law. Hence, the effective informational asymmetries are the agent's level of wealth and his efficiency level of safety. This extends the models of Shavell (1984), (1986), (1987) or Landes and Posner (1989) to informational asymmetries.

2.1.2 *The Complete Information Optimal Contract*

a) *The first-best safety level*

We assume first that there is no information asymmetry between the principal and the agent (either in efficiency or in wealth). Then, the RA can perform an appropriate transfer. The efficient care levels are obtained by equating the principal's marginal value and the agent's marginal cost. Hence, we have the following first-order conditions from [6]:

$$S'(\underline{e}^*) = \underline{\theta} + p'(\underline{e}^*)D \quad [7]$$

And,

$$S'(\overline{e}^*) = \overline{\theta} + p'(\overline{e}^*)D \quad [8]$$

The complete information efficient safety level $\underline{e}^*$ and $\overline{h}^*$ should be carried out if their social values, respectively $\underline{W}^* = S(\underline{e}^*) - \underline{\theta}\,\underline{e}^* - p(\underline{e}^*)D$ and $\overline{W}^* = S(\overline{e}^*) - \overline{\theta}\overline{e}^* - p(\overline{e}^*)D$ are non-negative. We can settle proposition 1

Proposition 1: *If* $\underline{W}^* = S(\underline{e}^*) - \underline{\theta}\,\underline{e}^* - p(\underline{e}^*)D$ *and* $\overline{W}^* = S(\overline{e}^*) - \overline{\theta}\overline{e}^* - p(\overline{e}^*)D$ *are non-negative, then:*

$$S(\underline{e}^*) - \underline{\theta}\,\underline{e}^* - p(\underline{e}^*)D \geq S(\overline{e}^*) - \underline{\theta}\overline{e}^* - p(\overline{e}^*)D \geq S(\overline{e}^*) - \overline{\theta}\overline{e}^* - p(\overline{e}^*)D \quad [9]$$

(Proof in appendix).

This relationship involves that the social value of the protection level is higher when the agent is efficient than when it is not.

b) *Implementing the first-best*

For a successful delegation of the task, the principal has to offer the agent a utility level that is at least as high as the level the agent obtains outside the relationship. These are the agent's participation constraints. Then, the quo-utility level or participation constraints write as:

$$\underline{t} - \underline{\theta}\,\underline{e} - p(\underline{e})\underline{y} \geq 0 \qquad [10]$$

$$\bar{t} - \bar{\theta}\bar{e} - p(\bar{e})\bar{y} \geq 0 \qquad [11]$$

To implement the first-best production levels, the principal makes a contract of a take-it or leave-it type to the agent and supply a $(\underline{t}^*, \underline{e}^*)$-contract for the efficient agent ($\underline{\theta}$) or a $(\bar{t}^*, \bar{e}^*)$-contract for the inefficient one ($\bar{\theta}$). Hence, under symmetric information assumption, the principal needs to know perfectly the agent's wealth level to perform an appropriate payment. Indeed, the transfer t includes both the safety price and the risk cover.

3. Asymmetric information and information rents: the case of standard strict liability

Now, we analyze the situation characterized by information asymmetries (efficiency and wealth) between the RA and the agent in a standard strict liability framework. Hence, if he is found liable for the harm, the agent will have to repair it by engaging the whole of his assets.

3.1 The agent program under standard strict liability

The agent knows privately both how efficient he is and his wealth level. These values are ignored by the principal. Then, he has to design an incentive mechanism that will reveal this double information. Conform to standard asymmetric information theory (Laffont-Martimort, 2002, chap.2)), a menu of contracts $\mathcal{C} = \{(\underline{t}, \underline{e}), (\bar{t}, \bar{e})\}$ is incentive compatible when $(\underline{t}, \underline{e})$ is weakly preferred to $(\bar{t}, \bar{e})$ by the agent $\underline{\theta}$ and $(\bar{t}, \bar{e})$ is weakly preferred to $(\underline{t}, \underline{e})$ by the agent $\bar{\theta}$. This involves that the following constraints (incentive compatibility constraints) have to be respected:

$$\underline{t} - c(\underline{\theta}, \underline{e}, \underline{y}) \geqq \bar{t} - c(\underline{\theta}, \bar{e}, \underline{y}) \qquad [12]$$

$$\bar{t} - c(\bar{\theta}, \bar{e}, \bar{y}) \geqq \underline{t} - c(\bar{\theta}, \underline{e}, \bar{y}) \qquad [13]$$

A supplementary condition is that participation constraints have to be respected too:

$$\underline{t} - c(\underline{\theta}, \underline{e}, \underline{y}) \geqq 0 \qquad [14]$$

$$\bar{t} - c(\bar{\theta}, \bar{e}, \bar{y}) \geqq 0 \qquad [15]$$

The menu of contracts is incentive feasible if the constraints [12] to [15] are satisfied. Contracts in $\mathcal{C}$ are truthful, i.e. the firm is induced to report its true technological parameters. We define the information rents of the agent of each type as:

$$\underline{U} = \underline{t} - c(\underline{\theta}, \underline{e}, \underline{y}) \quad [16]$$

$$\overline{U} = \overline{t} - c(\overline{\theta}, \overline{e}, \overline{y}) \quad [17]$$

Then we can define the amount that an efficient agent can capture by mimicking an inefficient agent. However, the risk question makes this point more delicate. Hence, if the efficient agent can mimic the $\overline{\theta}$ agent by adapting its supply of security service, *a priori*, he cannot imitate the $\overline{\theta}$ agent's level of wealth $\overline{y}$ which is unknown to him... Furthermore, in the case of an accident, his effective wealth will be engaged. Hence, the informational rent depends only on the level of supplied safety which expresses as:

$$\underline{U} = \underline{t} - c\left(\underline{\theta}, \underline{e}, \underline{y}\right) \geqq \underline{t} - c\left(\underline{\theta}, \overline{e}, \underline{y}\right).$$

Or, still:

$$\underline{U} = \overline{t} - c(\overline{\theta}, \overline{e}, \overline{y}) - c(\underline{\theta}, \overline{e}) + c(\overline{\theta}, \overline{e}, \overline{y}) = \overline{U} - \left(\underline{\theta}\overline{e} + \underline{y}\, p(\overline{e})\right) + \left(\overline{\theta}\overline{e} - \overline{y}\, p(\overline{e})\right)$$

$$\underline{U} = \underline{t} - c(\underline{\theta}, \underline{e}) \geqq \overline{U} + \Delta\theta\overline{e} - \Delta y p(\overline{e}) \quad [18]$$

(Where $\Delta\theta = \overline{\theta} - \underline{\theta} > 0$ and $\Delta y = \underline{y} - \overline{y}$).

Let us note one cannot know *a priori* if the wealth difference Δy is positive or negative. Indeed, we cannot postulate that the efficient agent has to be richer than the inefficient one or the reverse. The consequences of both designs have to be discussed.

3.2 The program of the principal under standard strict liability

To overcome the uncertainty induced by informational asymmetries, the principal offers a menu of contracts. Before defining his complete program, we have to define the regulator's expected gain which expresses as:

$$(S(e) - t)(1 - p(e)) + (S(e) - t - (D - y))p(e) = S(e) - (D - y)p(e) - t$$

Then, taking into account the nature of the agent, the principal's program writes as:

$$Max_{\{(\underline{t},\underline{e}),(\overline{t},\overline{e})\}}\, \vartheta\left(S(\underline{e}) - \left(D - \underline{y}\right)p(\underline{e}) - \underline{t}\right) + (1 - \vartheta)(S(\overline{e}) - (D - \overline{y})p(\overline{e}) - \overline{t}) \quad [19]$$

Subject to the constraints [12] to [15].

Considering the information rents $\underline{U} = \underline{t} - c(\underline{\theta}, \underline{e}, \underline{y})$ and $\overline{U} = \overline{t} - c(\overline{\theta}, \overline{e}, \overline{y})$.

We can replace the value of the transfers by the information rents, and, then, the program becomes:

$$Max_{\{(\underline{U},\underline{e}),(\overline{U},\overline{e})\}}\vartheta\left(S(\underline{e}) - \underline{\theta}\,\underline{e} - D\,p(\underline{e})\right) +$$

$$(1-\vartheta)(S(\overline{e}) - \overline{\theta}\,\overline{e} - D\,p(\overline{e})) - (\vartheta\underline{U} + (1-\vartheta)\overline{U}) \quad [20]$$

Subject to the incentive constraints:

$$\underline{U} \geqq \overline{U} + \Delta\theta\overline{e} - \Delta y p(\overline{e}) \quad [12']$$

$$\overline{U} \geqq \underline{U} - \Delta\theta\underline{e} + \Delta y p(\underline{e}) \quad [13']$$

And the participation constraints:

$$\underline{U} \geqq 0 \quad [14']$$

$$\overline{U} \geqq 0 \quad [15']$$

The principal aims first at maximizing the net safety surplus and, second, minimizing the information rents. In general, following standard presentation (Laffont-Martimort, 2002), finding solution to this program involves choosing the relevant constraints, i.e. the binding ones at the optimum. Hence, the relevant constraints are reduced from four to two: the incentive constraint of the efficient agent and the participation constraint of the $\overline{\theta}$ agent. Now, taking into account the severe accident occurrence, this simplification has to be made cautiously because the agent's wealth is privately known and this adds a supplementary uncertainty.

Proposition 2: *Considering standard strict liability regime, when the probability of severe accident with social impact (health or environment) is introduced, the revelation mechanism depends on the wealth of each category's of agent. Considering the program [20] to[15'], the necessary condition for solving it is that* $\underline{y} > \overline{y}$.

(Proof in appendix).

This proposition means that when the inefficient agent is richer than the efficient one, then the usual mechanism that involves that efficient agent will supply the first best level of effort does not work anymore. Indeed, [15'] ($\underline{U} \geqq 0$) cannot be respected (this value can be negative). The efficient agent ignores if his assets are higher than the ones of the inefficient agent and he is deterred to participate.

If $\underline{y} > \overline{y}$, (proposition 2 fulfilled), the remaining relevant constraints are [12'], and [15'], and both of them have to be binding. Consequently:

$$\underline{U} = \Delta\theta\overline{e} - \Delta y p(\overline{e}) \quad [12'']$$

And,

$$\overline{U} = 0 \quad [15'']$$

Implementing them into the principal's program, we get:

$Max_{\{(\underline{e},\overline{e}\}}\vartheta\left(S(\underline{e})-\underline{\theta}\,\underline{e}-Dp(\underline{e})\right)+(1-\vartheta)(S(\overline{e})-\overline{\theta}\overline{e}-Dp(\overline{e}))-\vartheta(\Delta\theta\overline{e}-\Delta yp(\overline{e}))$ [20']

From the analysis of the first order conditions, we deduce the informational rents that the efficient agent can capture. Indeed, if the inefficient agent gets no rent by mimicking the $\underline{\theta}$ agent, the efficient agent may acquire information rent. We note by "SB" the second best optimal values. The first order conditions are given by:

$$S'(\underline{e}^{SB}) = \underline{\theta} + Dp'(\underline{e}^{SB}) \qquad [21]$$

This corresponds to the first best value of $\underline{e}$ and $\underline{e}^{SB}$=$\underline{e}^{*}$. The informational rent of the principal is then equal to $\underline{U} = \Delta\theta\overline{e}^{SB} - \Delta yp(\overline{e}^{SB})$. Concerning the inefficient agent:

$$(1-\vartheta)(S'(\overline{e}^{SB}) - \overline{\theta} - Dp'(\overline{e}^{SB})) = \vartheta(\Delta\theta - \Delta yp'(\overline{e}^{SB}))\text{-} \qquad [22]$$

[22] expresses the tradeoff between efficiency and rent extraction. Here $\vartheta\left(\Delta\theta - \Delta yp'(\overline{e}^{SB})\right) > 0$ because $p'(\overline{e}^{SB}) < 0$, $\Delta y > 0$ and $\Delta\theta$>0. The question is to know if this condition is compatible with the monotonicity condition that can be deduced from [12'] and [13']. It appears from them that:

$$0 \geqq \Delta\theta(\overline{e}^{SB} - \underline{e}^{SB}) - \Delta y(p(\overline{e}^{SB}) - p(\underline{e}^{SB}))$$

By assumption $\Delta y > 0$, $p(\overline{e}^{SB}) - p(\underline{e}^{SB})$>0 because $\underline{e}^{SB}$=$\underline{e}^{*}$ hence $\Delta y\left(p(\overline{e}^{SB}) - p(\underline{e}^{SB})\right) > 0$ and $-(\Delta y\left(p(\overline{e}^{SB}) - p(\underline{e}^{SB})\right) < 0)$. Furthermore, $\Delta\theta > 0$ and $\overline{e}^{SB} - \underline{e}^{SB} < 0$, then the proposition is verified and we get the following relationship:

$$\underline{e}^{*} = \underline{e}^{SB} > \overline{e}^{*} > \overline{e}^{SB} \qquad [23]$$

Now we can determine the level of the second best transfers taking into account the information rents. For that, we recall that from the definition of the information rent:

$$\underline{U}^{SB} = \underline{t}^{SB} - c(\underline{\theta}, \underline{e}^{SB}) = \Delta\theta\overline{e}^{SB} - \Delta yp(\overline{e}^{SB})$$

Then, $\underline{t}^{SB} - \underline{\theta}\,\underline{e} - \underline{y}\,p(\underline{e}) = \Delta\theta\overline{e}^{SB} - \Delta yp(\overline{e}^{SB})$ [24]

As a consequence:

$$\underline{t}^{SB} = \underline{\theta}\,\underline{e}^{*} + \underline{y}\,p(\underline{e}^{*}) + \Delta\theta\overline{e}^{SB} - \Delta yp(\overline{e}^{SB}) \qquad [25]$$

And,

$$\overline{t}^{SB} = \overline{\theta}\,\overline{e}^{SB} + \overline{y}\,p(\overline{e}^{SB}) \qquad [26]$$

These results differ slightly with standard asymmetric information theory. They call for some remarks.

Remark 1: It is legitimate to consider that $\Delta\theta = \overline{\theta} - \underline{\theta} > 0$, that expresses the difference in efficiency of agent $\underline{\theta}$ compared to agent $\overline{\theta}$ considering marginal costs. However, there is no economic legitimacy putting $\Delta y = \underline{y} - \overline{y} > 0$ (or the reverse) as an assumption. Proposition 2 results from a strong assumption. However, in general, there is no economic reason to consider that the efficient agent should be richer than the inefficient one or the reverse.

Remark 2: We can check that the informational rent of the efficient agent is positive only if: $p(\underline{e}^*) > \left(1 - \frac{\overline{y}}{\underline{y}}\right) p(\overline{e}^{SB})$ with $1 > \frac{\overline{y}}{\underline{y}} > 0$ (proof in appendix);

If this condition is not met, then the value of the informational rent can be weak. Concretely, this condition means that the difference between the efforts brought by the efficient agent compared to the inefficient one, has to be higher than $\frac{\overline{y}}{\underline{y}} p(\overline{e}^{SB})$.

Remark 3: Under a standard strict liability regime under an asymmetric information assumption, the efficient agents may be deterred to enter in the game. Indeed, two conditions have to be met to induce him to compete. The first one is necessary but insufficient (proposition 1) i.e. his level of wealth has to be higher than the one of the inefficient agent. The other condition, (sufficient) is that the level of safety effort has to be high enough such that the difference in the probability of accident will exceed $\frac{\overline{y}}{\underline{y}} p(\overline{e}^{SB})$.

We have to underline that this condition is particularly stringent because the efficient agent must know too much information before accepting the delegation. Indeed, the efficient agent cannot know the nature of his opponent's wealth.

Remark 4: The constraint [13'] ($\overline{U} \geqq \underline{U} - \Delta\theta\underline{e} + \Delta y p(\underline{e})$) means that the inefficient agent claims that he is efficient but he will fail to supply the promised level of safety. This is typically an adverse selection problem. However, it cannot be solved here because instruments that could induce the efficient agent to overcome his reluctance to produce when conditions are not favorable are lacking.

As a conclusion, standard strict liability is not a powerful instrument to protect public health and the environment. This result has long been known (Shavell, 1986)) and asymmetric information reinforce the point. We show furthermore that uncertainty about wealth level under this regime tends to favor the adverse selection effect. This state of matter introduces biases in the calculus of the efficient agent.

4. The Capped strict liability scheme and asymmetric information

In this paragraph two points will be discussed: first, the way to get an acceptable solution for the strict liability scheme and second, the consequences for a better involving of associated financing institution. Hence capped liability allow to secure investment and makes easier insuring investment.

4.1 A solution for the ceiling of liability

Now we make the assumption that Law limits the amount of repairs. The ceiling of damages should preserve the wealth of the agent: $C < y < D, C > 0$. This induces to modify generically the cost function as:

$$C(e, \theta, y) = \theta e + C\, p(e) \quad [27]$$

As previously, the informational rent expresses as:

$$\underline{U}^C = \underline{t} - c(\underline{\theta}, \underline{e}, \underline{y}) \geqq \overline{t} - c(\underline{\theta}, \overline{e}, \underline{y}) \quad [28]$$

And, processing as before when we got equation [18]:

$$\underline{U}^C \geqq \overline{U}^C + \Delta\theta\overline{e} \quad [29]$$

(Where the index C to $\underline{U}^C$ and $\overline{U}^C$ indicates that the new liability regime is capped strict liability and where $\Delta\theta = \overline{\theta} - \underline{\theta} > 0$). Using the same argument for $\overline{U}^C$:

$$\overline{U}^C = \overline{t} - c(\overline{\theta}, \overline{e}, \overline{y}) \geqq \underline{U}^C - \Delta\theta\overline{e} \quad [30]$$

The principal's program becomes now (simplification in the appendix) (Program PC):

$$Max_{\{(\underline{U}^C, \underline{e}), (\overline{U}^C, \overline{e})\}} \vartheta\left(S(\underline{e}) - \underline{\theta}\,\underline{e} - D\,p(\underline{e})\right) + (1-\vartheta)\left(S(e) - \overline{\theta}\,\overline{e} - Dp(\overline{e})\right) - (\vartheta\underline{U}^C + (1-\vartheta)\overline{U}^C) \quad [31]$$

s.c.

$$\underline{U}^C \geqq \overline{U}^C + \Delta\theta\overline{e} \quad [32]$$

$$\overline{U}^C \geqq \underline{U}^C - \Delta\theta\overline{e} \quad [33]$$

$$\underline{U}^C \geqq 0 \quad [34]$$

$$\overline{U}^C \geqq 0 \quad [35]$$

As previously, we have to define which are the relevant constraints among the incentive compatibility and participation constraints. Relevancy means the binding ones at the optimum level. We consider contracts without collapse, i.e. $\overline{e} > 0$. This is verified when the Inada condition $S'(0) \to +\infty$ is satisfied and $\lim_{e\to 0} S'(e)\, e = 0$. The participation constraint of the efficient agent in [34] is always satisfied because [32] and [35] involves [34]. In this context, the inefficient agent has no interest mimicking efficiency, then [33] is irrelevant. After this simplification, two constraints are remaining the $\underline{\theta}$ -agent's incentive compatible constraint [32] and the participation constraint of the $\overline{\theta}$ -agent [35]. Getting the optimum of the PC program involves that both constraint must be binding:

$$\underline{U}^C \geqq \Delta\theta\overline{e} \quad [36]$$

And,

$$\overline{U}^C = 0 \quad [37]$$

This reduces the objective function of the program (PC) becomes:

$$Max_{\{\underline{e},\overline{e}\}}\, \vartheta\left(S(\underline{e}) - \underline{\theta}\,\underline{e} - D\,p(\underline{e})\right) + (1-\vartheta)\left(S(\overline{e}) - \overline{\theta}\,\overline{e} - D\,p(\overline{e})\right) - \vartheta\Delta\theta\overline{e} \quad [38]$$

As in standard representations, asymmetric information modifies the principal's optimization by the subtraction of the expected rent that has to be given up to the $\underline{\theta}$ agent. This rent depends on the level of effort requested from the inefficient type. From the first order conditions we draw the equilibrium values which are identical to the full information setting for the efficient agent.

$$S'(\underline{e}^{SB}) = \underline{\theta} + Dp'(\underline{e}^{SB}), \quad [39]$$

And for the inefficient one:

$$S'(\overline{e}^{SB}) - \overline{\theta} = \frac{\vartheta}{(1-\vartheta)}\Delta\theta \quad [40]$$

We can check that with a similar argument made for the standard liability scheme we define the following relationship that follows from the monotonicity of the second-best schedule of safety level:

$$\underline{e}^* = \underline{e}^{SB} > \overline{e}^* > \overline{e}^{SB\prime} \quad [41]$$

(Where $(".\text{"}^{SB\prime})$ stands for the second best under the capped regime). In summary, we can draw the following proposition:

Proposition 3: *Under asymmetric information, under a cap strict liability regime, the optimal contracts entail:*

- *No safety effort distortion for the $\underline{\theta}$ agent in respect to the first best $\underline{e}^* = \underline{e}^{SB}$ and a downward distortion for the $\overline{\theta}$ type, gives:*
  $S'(\overline{e}^{SB}) - \overline{\theta} = \frac{\vartheta}{(1-\vartheta)}\Delta\theta$, *with* $\overline{e}^* > \overline{e}^{SB\prime}$.
- *Only the efficient type gets a positive information rent given by:*
  $$\underline{U}^C = \Delta\theta\overline{e} \quad [42]$$
- *The second best transfers are respectively:*
  $$\underline{t}^{SB} = \underline{\theta}\,\underline{e}^* + Cp(\underline{e}^*) + \Delta\theta\overline{e}^{SB\prime} \quad [43]$$
  And

$$\overline{t}^{SB} = \overline{\theta}\overline{e} + C\, p(\overline{e}^{SB}) \quad [44]$$

(Proof is deduced from the previous argument).

The ceiling of liability allows dropping the unknown level of wealth. Indeed, by [29] and [30] the value of the ceiling replaces the agent's wealth. Hence, the problem reduces to only one private information variable: the safety effort efficiency. The result that follows is quite standard. Under the ceiling of redress, the level of precautionary effort of the most efficient agent corresponds to the first rank of the symmetric information scheme. The counterpart is that this agent benefits of an informational rent that, however, is minimized by the optimal contract between the RA and the efficient agent.

4.2 Capped liability and insurance: an introduction

Conversely to a well shared opinion, the above results show that ceiling the redress level leads neither to overinvest in safety effort nor to under-invest in it if the principal can impact on the level of safety. Under asymmetric information, putting caps on redress issues on the same level of effort than the delegation of the risky activity under both symmetric information and the standard strict liability regime. After this initial result, many avenues must be explored. For instance, we have not addressed the issue of insurance which for capped liability is an important matter (Shavell, 2005), (Boyd and Ingerman, 1997)). For instance, it is compulsory for oil operators in the maritime sector and the nuclear industry to subscribe insurance against technological risk. In this paper, we have limited our concern to study the scope and power of the *ex-post* regulatory control based on the ceiling of redress under informational asymmetries on agent's wealth and efficiency.

By fixing the ceiling of the redress, the RA reduces the uncertainty involved by the unknown wealth of polluters. Furthermore, the RA can control the agent's activity by by demanding that candidates to delegation should own at least the amount of the cap as financial guarantee. This induces insufficient funded agents to withdraw. This may be done either on the own assets of the agent or by the help of an insuring company. For instance, if Q is that level that is insured, where:

$C - Q = w$ (w is this share of the agent's wealth which is used as commitment). As a consequence, the agent has to cope with two principals: the RA and the insurance company. Indeed, we can consider that the insurance premium is equivalent to $Qp(e) = m$, that is to say the probability of an accident by the claim of the company. As a result, to reduce his premium the agent has to increase his level of effort. Indeed, the insurance company has to check that the level of safety corresponds to the level of the insurance premium. A next step will be to develop these relationships.

5. Conclusion

Under asymmetric information, standard strict liability rules fail to provide the first best level of safety effort. This favors adverse selection emergence and can induce inefficient firms to undertake risky activities by deterring the efficient ones. Capped strict liability may be an alternative to strict liability. However, this switching does not guarantee automatically restoring efficiency. Indeed, some necessary conditions have to be fulfilled.

In real life, as far as informed people perceive that the ceiling is insufficient, capped strict liability raise strong opposition. In this paper we showed that, under asymmetric information, the Principal has to formulate relevant contracts that put together caps and level of safety effort. These contracts are second best contracts compared to the certain case under strict liability, but they adjust the level of safety to the level of the cap. At the equilibrium level, the level of care has to be chosen such that the marginal costs of care are offset by marginal reductions in expected damages. To be fully efficient, a capped strict liability scheme needs to associate the utility level of the principal to a relevant level of security. This involves establishing a tradeoff between a relevant safety effort and its associated costs and the level of redress designed by the level of the cap. Indeed, this tradeoff balances the risk level that the principal can accept and the amount of the fund dedicated to repairs.

Capping the repairs level does not remove the judgment-proof question even if an efficient contract is formulated. However, it locks up the debate by explicitly involving all the parties. Hence, at the equilibrium, implicitly, the principal accepts incomplete repairs but the potential loss is balanced by an increase in safety. These one consists in two points. First, the equilibrium level of effort is calculated on the whole cost of damage that the society can endure. The effort level is identical to the one of the certainty case reached under strict liability. Second, the contract attracts the safety efficient agent and avoids the adverse selection effect. This eviction effect of safety inefficient agent can be reinforced by the requirement of insurance policy that introduces a new principal in the scheme.

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Appendix

The society welfare function:

$$W = S(e)\big(1 - p(e)\big) + \big(S(e) - (D - K)\big)p(e) - C(e) \Rightarrow$$

$$W = S(e)\big(1 - p(e)\big) + \big(S(e) - (D - K)\big)p(e) - \theta e - p(e)K =$$

$W = S(e) - \theta e - p(e)D$ for $\theta \in [\overline{\theta}, \underline{\theta}]$ and $K = \{C, y\}$.

Proof of proposition 1

To see this point we note that because, $p(\underline{e}) < p(\overline{e})$, then $p(\underline{e}^*)D - p(\overline{e}^*)D < 0$, and $S(\underline{e}^*) - \underline{\theta}\,\underline{e}^* > 0$, $S(\overline{e}^*) - \overline{\theta}\overline{e}^* > 0$ and $S(\underline{e}^*) - \underline{\theta}\,\underline{e}^* \geq S(\overline{e}^*) - \underline{\theta}\overline{e}^* \geq S(\overline{e}^*) - \overline{\theta}\overline{e}^*$, is verified then, $S(\underline{e}^*) - \underline{\theta}\,\underline{e}^* - p(\underline{e}^*)D \geq S(\overline{e}^*) - \underline{\theta}\overline{e}^* - p(\overline{e}^*)D \geq S(\overline{e}^*) - \overline{\theta}\overline{e}^* - p(\overline{e}^*)D$ is verified too.

Proof of proposition 2

Hence, having $\underline{U} \geqq 0$ [14'] cannot be considered as granted. Preliminary conditions have to be formulated. $\underline{U} \geqq 0$ means that if $\overline{U} \geqq 0$ is binding ($\overline{U} = 0$) then this involves that: $\underline{U} = \Delta\theta\overline{e} - \Delta y p(\overline{e}) \geqq 0$ or, still, $\Delta\theta/\Delta y \geqq p(\overline{e})/\overline{e}$, by definition $p(\overline{e})/\overline{e} > 0$ (with $p(\overline{e})/\overline{e} \to 0$), furthermore, by definition, $\Delta\theta > 0$ then, the condition for having $\Delta\theta/\Delta y > 0$ is that $\Delta y > 0$ i.e. $\underline{y} > \overline{y}$ because $\Delta\theta > 0$. Hence, the condition for having $\underline{U} \geqq 0$ is that $\underline{y} > \overline{y}$. That means that if the efficient agent is less rich than the inefficient one, then the participation constraint cannot be fulfilled.

Proof of remark 2

Starting from

$$\underline{t}^{SB} = \underline{\theta}\,\underline{e}^* + \underline{y}\,p(\underline{e}^*) + \Delta\theta\overline{e}^{SB} - \Delta y p(\overline{e}^{SB})$$

We study the conditions for which:

$\underline{y}\,p(\underline{e}^*) - \Delta y p(\overline{e}^{SB}) \geq 0$ or still $\underline{y}\,p(\underline{e}^*) - (\underline{y} - \overline{y})p(\overline{e}^{SB}) \geq 0$, under the respect of proposition 2, the results ensues:

$$p(\underline{e}^*) > \left(1 - \frac{\overline{y}}{\underline{y}}\right)p(\overline{e}^{SB}).$$

Getting the program

$$Max_{\{(\underline{t},\underline{e}),(\overline{t},\overline{e})\}}\ \vartheta\big(S(e) - (D - C)p(\underline{e}) - \underline{t}\,\big) + (1 - \vartheta)(S(\overline{e}) - (D - C)p(\overline{e}) - \overline{t}\,)$$

Subject the constraints of incentive compatibility:

$$\underline{t} - \underline{\theta}\,\underline{e} - Cp(e) \geqq \overline{t} - \underline{\theta}\,\overline{e} - C\,p(\overline{e})$$

$$\overline{t} - c(\overline{\theta}, \overline{e}) \geqq \underline{t} - c(\overline{\theta}, \underline{e})$$

And the supplementary condition of the participation constraints that have to be respected too:

$$\underline{t} - \underline{\theta}\,\underline{e} - Cp(\underline{e}) \geqq 0$$

$$\overline{t} - \overline{\theta}\overline{e} - C\,p(\overline{e}) \geqq 0$$

As previously, we can cancel the transfers $\underline{t}$, $\overline{t}$ and replacing them by the informational rents, we get the PC program.

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