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Gérard Mondello

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Strict Liability, Capped Strict Liability
And
Care Effort Under Asymmetric Information

By
GERARD MONDELLO*

This paper compares the effectiveness of strict liability and capped strict liability regimes in an agency relationship among a regulatory agency and operators of risky activities. Under a double asymmetric information assumption (wealth and efficiency in care effort), it shows that capping liability is more efficient than keeping with strict liability, this at the price of an informational rent. Efficiency means that the efficient agent supplies the level of safety effort equivalent to the first best solution one. At the optimum, this rent is minimized by the efficient contract supplied by the principal. (JEL: K0, K32, Q01, Q58)

1. *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. Productive activities generate potential huge harm with large ripple and irreversible effects on public health or natural resources. Hence, nowadays, one major task of governments and risky activities corporate managers is to find effective tradeoffs between natural resources preservation and economic growth. Environmental and economic policy should achieve such a balance by combining optimally ex ante regulation instruments (taxes, permits, standards, etc.) and ex post liability regimes (KOLSTAD, UHLEN AND JOHNSON [1990]), (SCHMITZ [2000]). The range of ex ante and ex post environmental regulatory instruments is wide. Then, harmonizing these tools constitutes a major stake for environmental policies.

However, the present paper will not take the road of optimally combining these instruments. Its scope is limited to a comparative analysis within the field of strict liability regimes applied to environmental protection. Its object is to

*University of Nice Sophia Antipolis, Groupe de Recherche en Droit, Economie, Gestion (GREDEGUMR 7321), Centre de recherche en droit économique (CREDECO), Centre National de la Recherche Scientifique (CNRS). I would like to thank the referees for valuable comments. I remain of course solely responsible for the content and shortcomings of this paper.

determine the best strict liability regime that induces the operators of risky activities to supply the optimal care effort under asymmetric information. It studies the agency relationship between a principal (a government through for instance a regulatory agency) and an operator (agent) who exploits a risky facility. The principal has to induce the agent to provide the highest safety level against financial transfers. Confining the analysis range to the strict liability question allows restricting the field to the ex post liability question only. Indeed, after a harm occurrence, Courts do not seek the misconduct or the negligence of the polluter as under a negligence rule regime. Under strict liability, Courts have only to check the causal link between the harm and the risky activity. Indeed, this causation is sufficient to assess whether the operator's actions have involved the accident or not, this, regardless of the level of care exercised beforehand by the manager. Conversely, under negligence rule, Courts have to assess the operator's compliance with law, rules and the optimal level of care to determine whether a fault has been committed or not. For instance, typically, KOLSTAD, UHLEN AND JOHNSON [1990] or, still, BOYER AND PORRINI [2006] and [2008] lead their analysis under a negligence rule.

Nowadays, strict liability regimes are implemented to protect the environment as under CERCLA in the United States¹ or, still, the directive on Environmental liability in European Union². The enforcement of such regimes strives towards twofold objectives: first compensating and repairing damage and, second, inducing the potential polluters to take preventive measures still reaching the optimal level. Without a doubt, this regime advantages victims that can access rapidly to compensation without bearing the burden of the proof of the fault. However, its weaknesses are several. First, redresses can exceed the polluter's financial capacities and lead him to become judgment proof (SUMMERS [1983]), (SHAVELL [1986]). This induces a de facto limited liability. Second, Society as a whole will endure the cost of the incomplete internalization. Third, as a consequence, the level of care could be undersized (SHAVELL [1986]). However, this last point is controversial as shown below. Fourth, the potential polluter can strategically organize his judgment-proofness (VAN'T VELD, RAUSSER AND SIMON [1997], VAN'T VELD [2006]). Fifth, the level of investment can be discouraged when strict liability is extended to lenders (BOYER AND LAFFONT [1995] and [1997]).

Some sensitive sectors as the maritime transportation and the electro-nuclear industry have reacted to the negative effects of strict liability by putting caps on the level of repairs. The operator is exposed to a level of redress substantially lower than the amount of the harm. This lightened responsibility

¹ *Comprehensive Environmental Response, Compensation and Liability Act (CERCLA)* (1980) and *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, L143/56, 30/4/04). See also OECD [2009].

should act as an investment incentive³. For instance, the International Convention on Liability and Compensation for Bunker Oil Pollution Damage of 2001 stated the strict liability of ship-owners for all types of pollution damage caused by bunker oil and binds the repairs to an amount calculated in accordance with the amended 1976 Convention on Limitation of Liability for Maritime Claims (SIOPCF [2009]). 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 last notion applies only to people privately concerned by personal losses. 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, this fund proved to be too low.

Nuclear civil liability is also based on caps on the redresses⁴. Developing nuclear industry involves relieving nuclear operators of the burden of potentially ruinous liability claims⁵. They establish a strict liability regime channeled exclusively to the operators of the nuclear installations. If this liability is absolute, it is limited in time and amount which is set to €1.500M (see WORLD NUCLEAR ASSOCIATION [2009]). At the political level, this analysis is echoed by opponents to the introduction of such liability regimes⁶.

From an economic viewpoint, industrial accidents are negative externalities that disturb the classical agency relationship 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 will not get the first-best outcome. This paper shows that under asymmetric information, under a strict liability regime, the principal cannot expect from the operator the first rank level of prevention of symmetric information. Paradoxically this last one is reached when is relaxed the strict liable

³ See for instance BOYD [2001, p.47]: "[...] *that environmental costs above the cap will be uncompensated by responsible parties* (emphasis added)."

⁴ See the IAEA's Vienna Convention of 1963, OECD's Paris Convention of 1960, the Convention on Supplementary Compensation for Nuclear Damage (CSC) of 1997 and 2003, the OECD Paris (and Brussels) amended in 2004. For the USA, the Price-Anderson Act limits insurance to \$300 million and caps the operators' liability to \$10.5 billion.

⁵ See OECD, Nuclear Energy Agency (NEA) [1982] "*Exposé des Motifs, Motif 45*" or still (SCHWARTZ [2006, p.39]).

⁶ In India, see the opposition in 2010 to the Proposed Civil Nuclear Liability [Cap] Bill <http://www.sacw.net/article1288.html>. See also (ANDERSON AND AHMED [1996]).

regime for a less rigorous one: the capping of redress. Basically, our model assumes the existence of twofold information asymmetry: first, the operator's safety efficiency is unknown from the government and, second, the agent's level of wealth is private information. This twice uncertainty is detrimental in the supplying of the first-best level of safety. Then, it is shown that capping the amount of repairs leads the efficient agents to supply the first best solution against, as a price, a minimized informational rent. Indeed, capping the level of repairs removes one level of uncertainty.

This contribution brings some answers to the controversy about the effective impact of bound on repairs. Following SHAVELL [1986], some authors consider that caps induce operators to lower their safety effort because they proportionate it to the level of redress (FAURE AND HU[2006]), (FAURE AND WANG[2008]). Furthermore, under the ceiling of repairs, the internalization process remains structurally incomplete because the victims' rights to full compensation are seriously impaired. It is a kind of limitation for a liability already limited by wealth.

However, the debate is open because other authors consider that limiting institutionally the amount of the polluters' repair may induce them to increase the safety level beyond the optimal level (JOST [1996], MICELI AND SEGERSON[2003]), (DARI-MATTIACCI[2006]). These authors extend the analysis of (BEARD [1990]). These contributions insist 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]), (DARI-MATTIACCI AND DE GEEST [2006]). Here, we join the conclusion of this literature: an appropriate ceiling of repairs gives better results than a strict liability regime. The main difference is that, under asymmetric information, this regime leads to the first best level of prevention of a complete information situation under a standard strict liability regime (i.e. without cap).

This approach comes from the judgment-proof literature initiated by SUMMERS [1983] and SHAVELL [1986], followed by PITCHFORD [1995], BOYER AND LAFFONT [1997] or still HEYES [1996]. The object is to internalize the costs of damages by shifting the liability burden to vicarious or creditworthy third parties. Furthermore, operators have to choose an adequate level of preventive measures. This means the necessity of finding a trade-off between the amount dedicated to the repairs and the level of safety effort (BOYER AND LAFFONT [1997]). Under complete information this goal is reached, however, under asymmetric information, only the second best level of prevention can be achieved⁷.

⁷ HIRIART AND MARTIMORT [2006a] consider the optimal regulation of a risky project under a moral hazard assumption. By fines and rewards, the authors derive

In a first section, 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 second section shows that information asymmetry breaks this scheme because efficient agents are deterred to exert the risky activity. In a third section, capped liability is introduced and, there, is studied how the most efficient agent is led to supply the first rank level of effort. A fourth section concludes.

2. *Economic environment: technology, preferences, information*

This paper applies the methodology of asymmetric information theory, but, basically, it rests on the foundations of liability theory developed by SHAVELL [1986] because determining the optimal level of care is central. The principal corresponds to a government that expects from agents (operators of risky facilities) the highest level of safety. In our representation, agent and principal focus on safety mainly. That means that reference to the supplied quantity is only implicit. Indeed, the agents differ by the marginal costs of their safety effort. Regarding quantities, the principal considers that the marginal production costs of gross production are almost identical. The competitive difference is made by the level of safety brought by the operators. Putting it otherwise, if basic production technologies are roughly similar, they differ mainly by the level of safety that the agent embeds in it.

The range of application and relationship is wide. This may concern as well the relationships between government and utilities that supply environmental services as water, waste treatment, etc, but also the regulation of electro-nuclear plants, or energetic facilities. The transfers remunerate the supplementary efforts that improve safety beyond what is expected which is reflected in differentiated marginal costs⁸. This state of matter is a common feature considering most modern products and productions because knowledge about basic technology is available everywhere. Consequently, supplying a basic service as, for instance, fresh water, sewage, power, etc, can be achieved by any firm. However, efficiency in safety differs from an agent to another one. For instance electro-nuclear power may be supplied by highly secure plants or by less efficient ones as the Tchernobyl catastrophe in 1986 revealed it. Nowadays, for most products and production, competition bears more on quality or safety (here safety) than on 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 induce the

conditions under which extending liability to the principal improves social welfare. If the principal has all the bargaining power, then extended liability favors the internalization of environmental damage and so improves welfare (BALKENBORG [2001]).

⁸ 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])).

operators to supply the highest level of care. 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.). This belongs to the set of *ex ante* regulation. That involves the regular checking up of the quality and the safety of the products. For instance, steady 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 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. 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. 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 government through a regulatory agency (noted RA) wants to induce the operators of risky facilities to accompany the provision of their production or services with the highest level of safety. Compared to models that deals with liability and competition, as (PITCHFORD[1995]), (BOYER AND LAFFONT[1997]), (BOYD AND INGBERMAN [1997]), (HIRIART AND MARTIMORT[2006b]), the level of safety effort is dissociated from the efficiency about the skill of the firm in its management of safety. This could correspond for instance to the relationships between a facility (energy as a nuclear plant), and the government. The government through a set of transfers corresponding either to subsidies allocated for R&D for safety for instance, or for other motives associated with a care effort or through credit policy, or other government intervention as fixation of tariffs (KOPLOW[2004]) and (KOPLOW [2010 p.17]) will induce the operator to supply the highest safety effort. These transfers remunerate or pay the supplement of safety that is above the standard product.

Rather, here, the tradition initiated by SHAVELL [1986] will be followed and the present analysis will focus on the care effort level e , ($e \geq 0$). The Principal derives a benefit $S(e)$ from the acquisition of the good so long as it ensures an adequate level of safety e . $S(e)$ is defined on \mathbb{R} with $S'_e > 0$ and $S''_{ee} < 0$. Furthermore, this function satisfies the Inada condition: $S'(0) \rightarrow +\infty$ and $\lim_{e \rightarrow 0} S'(e) e = 0$.

Both regimes will be analyzed respectively, i.e. the strict liability one and the capped one. This last regime puts ceilings of the level of repairs. Let y be the level of the agent's wealth and D , the level of a major damage which exceeds the

agent's financial capacities ($y < D$). Under a standard liability regime, if a benevolent Court considers the agent liable, he will have to pay from his own assets. If these ones are insufficient, 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 the liable agents can 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 twofold: i) the level of safety effort and ii) the agent's wealth that cannot be considered as public information. This last assumption seems quite natural because the operator's effective wealth is private information.

2.2 The utility functions

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

$$(1) \quad V = S(e) - t,$$

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:

$$(2) \quad U = t - C(e, K).$$

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 $\theta \in [\underline{\theta}, \bar{\theta}]$ with $\underline{\theta}$ (respectively $\bar{\theta}$) the marginal safety effort cost of the efficient (resp. inefficient) agent). As agent's efficiency is private information, the regulatory agency assesses the following probability distribution on the distribution between efficient agent (ϑ) and inefficient ones ($1 - \vartheta$), ($1 \geq \vartheta \geq 0$).

Then, is defined 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:

$$(3) \quad C(\theta, e, K) = \theta e(1 - p(e)) + (\theta e + K)p(e)$$

or, after developing:

$$(4) \quad C(\theta, e, K) = \theta e + Kp(e),$$

for $\theta \in [\underline{\theta}, \bar{\theta}]$ and $K = \{C, y\}$.

Then, the profit function becomes:

$$(5) \quad U = t - C(\theta, e, K) = t - \theta e - Kp(e).$$

Then, the society's welfare function is deduced (see section A.1 in the Appendix):

$$(6) \quad W = U + V = S(e) - \theta e - p(e)D \text{ for } \theta \in [\underline{\theta}, \bar{\theta}].$$

This function is such that $W'(e) > 0$, and $W''(e) > 0$, because $S'(e) > 0$, $D > 0$ and $p'(e) > 0$. As for standard asymmetric information theory, the

contracting outcome can be defined. Here, the relevant variables are the level of effort e which is necessary to achieve an acceptable level of safety and the transfer t received by the agent. Let Ξ be the set of feasible allocations:

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

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], and [1987] or LANDES AND POSNER [1989] to informational asymmetries.

2.3 The Complete Information Optimal Contract

2.3.1 The first-best safety level

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

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

and,

$$(8) \quad S'(\bar{e}^*) = \bar{\theta} + p'(\bar{e}^*)D.$$

The complete information efficient safety level \underline{e}^* and \bar{e}^* should be carried out if their social values, respectively $\underline{W}^* = S(\underline{e}^*) - \underline{\theta}\underline{e}^* - p(\underline{e}^*)D$ and $\bar{W}^* = S(\bar{e}^*) - \bar{\theta}\bar{e}^* - p(\bar{e}^*)D$ are non-negative. Then, proposition 1 can be settled (its proof is brought in Appendix A.2):

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

$$(9) \quad S(\underline{e}^*) - \underline{\theta}\underline{e}^* - p(\underline{e}^*)D \geq S(\bar{e}^*) - \underline{\theta}\bar{e}^* - p(\bar{e}^*)D \geq S(\bar{e}^*) - \bar{\theta}\bar{e}^* - p(\bar{e}^*)D.$$

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

2.3.2 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:

$$(10) \quad \underline{t} - \underline{\theta}\underline{e} - p(\underline{e})\underline{y} \geq 0$$

$$(11) \quad \bar{t} - \bar{\theta}\bar{e} - p(\bar{e})\bar{y} \geq 0.$$

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 the agent is liable for the harm, he will have to repair by engaging the whole of his assets.

3.1 *The agent's program under standard strict liability*

The agent knows privately how efficient he is and his wealth level. These values are ignored by the principal who has to design an incentive mechanism that will reveal this double information. Conform to standard asymmetric information theory (LAFFONT AND 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:

$$(12) \quad \underline{t} - c(\underline{\theta}, \underline{e}, \underline{y}) \geq \bar{t} - c(\underline{\theta}, \bar{e}, \underline{y})$$

$$(13) \quad \bar{t} - c(\bar{\theta}, \bar{e}, \bar{y}) \geq \underline{t} - c(\bar{\theta}, \underline{e}, \bar{y}).$$

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

$$(14) \quad \underline{t} - c(\underline{\theta}, \underline{e}, \underline{y}) \geq 0$$

$$(15) \quad \bar{t} - c(\bar{\theta}, \bar{e}, \bar{y}) \geq 0.$$

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:

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

$$(17) \quad \bar{U} = \bar{t} - c(\bar{\theta}, \bar{e}, \bar{y}).$$

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 $\bar{\theta}$ agent by adapting its supply of security service, a priori, he cannot imitate the $\bar{\theta}$ agent's level of wealth \bar{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:

$$\underline{U} = \underline{t} - c(\underline{\theta}, \underline{e}, \underline{y}) \geq \underline{t} - c(\underline{\theta}, \bar{e}, \underline{y})$$

or, still:

$$\begin{aligned} \underline{U} &= \bar{t} - c(\bar{\theta}, \bar{e}, \bar{y}) - c(\underline{\theta}, \bar{e}) + c(\bar{\theta}, \bar{e}, \bar{y}) \\ &= \bar{U} - \left(\underline{\theta}\bar{e} + \underline{y}p(\bar{e}) \right) + \left(\bar{\theta}\bar{e} - \bar{y}p(\bar{e}) \right) \\ (18) \quad \underline{U} &= \underline{t} - c(\underline{\theta}, \underline{e}) \geq \bar{U} + \Delta\theta\bar{e} - \Delta yp(\bar{e}) \\ &\quad (\text{Where } \Delta\theta = \bar{\theta} - \underline{\theta} > 0 \text{ and } \Delta y = \underline{y} - \bar{y}). \end{aligned}$$

Knowing a priori whether the wealth difference Δy is positive or negative is impossible. 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:

$$(19) \quad \text{Max}_{\{(\underline{t}, \underline{e}), (\bar{t}, \bar{e})\}} \vartheta \left(S(\underline{e}) - (D - \underline{y})p(\underline{e}) - \underline{t} \right) + (1 - \vartheta) \left(S(\bar{e}) - (D - \bar{y})p(\bar{e}) - \bar{t} \right), \text{subject to the constraints (12) to (15).}$$

Considering the information rents $\underline{U} = \underline{t} - c(\underline{\theta}, \underline{e}, \underline{y})$ and $\bar{U} = \bar{t} - c(\bar{\theta}, \bar{e}, \bar{y})$, we can replace the value of the transfers by the information rents, and, then, the program becomes:

$$(20) \quad \text{Max}_{\{(\underline{U}, \underline{e}), (\bar{U}, \bar{e})\}} \vartheta \left(S(\underline{e}) - \underline{\theta}\underline{e} - Dp(\underline{e}) \right) + (1 - \vartheta) \left(S(\bar{e}) - \bar{\theta}\bar{e} - Dp(\bar{e}) \right) - (\vartheta\underline{U} + (1 - \vartheta)\bar{U}),$$

subject to the incentive constraints:

$$(12a) \quad \underline{U} \geq \bar{U} + \Delta\theta\bar{e} - \Delta yp(\bar{e})$$

$$(13a) \quad \bar{U} \geq \underline{U} - \Delta\theta\underline{e} + \Delta yp(\underline{e})$$

and the participation constraints:

$$(14a) \quad \underline{U} \geq 0$$

$$(15a) \quad \bar{U} \geq 0$$

The principal aims, first, at maximizing the net safety surplus and, second, minimizing the information rents. In general, following standard presentation (LAFFONT AND 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 $\bar{\theta}$ 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 $\underline{y} > \bar{y}$.*

PROOF: In appendix A3.

This proposition means that when the inefficient agent is richer than the efficient one, the usual mechanism that involves that efficient agent will supply the first best level of effort does not work anymore. Indeed, (15a) ($\underline{U} \geq 0$) 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, logically, he is deterred to participate.

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

$$(12b) \quad \underline{U} = \Delta\theta\bar{e} - \Delta y p(\bar{e})$$

and,

$$(13b) \quad \bar{U} = 0.$$

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

$$(20a) \quad \text{Max}_{\{\underline{e}, \bar{e}\}} \vartheta \left(S(\underline{e}) - \underline{\theta} \underline{e} - Dp(\underline{e}) \right) + (1 - \vartheta) \left(S(\bar{e}) - \bar{\theta} \bar{e} - Dp(\bar{e}) \right) - \vartheta (\Delta\theta\bar{e} - \Delta y p(\bar{e})).$$

From the analysis of the first order conditions, are deduced 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:

$$(21) \quad S'(\underline{e}^{SB}) = \underline{\theta} + Dp'(\underline{e}^{SB}).$$

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 $\underline{U} = \Delta\theta\bar{e}^{SB} - \Delta y p(\bar{e}^{SB})$. Concerning the inefficient agent:

$$(22) \quad (1 - \vartheta) \left(S'(\bar{e}^{SB}) - \bar{\theta} - Dp'(\bar{e}^{SB}) \right) = \vartheta (\Delta\theta - \Delta y p'(\bar{e}^{SB}))$$

(22) expresses the tradeoff between efficiency and rent extraction.

Here $\vartheta (\Delta\theta - \Delta y p'(\bar{e}^{SB})) > 0$ because $p'(\bar{e}^{SB}) < 0$, $\Delta y > 0$ and $\Delta\theta > 0$. The question is to know if this condition is compatible with the monotony condition that can be deduced from [12'] and [13']. It appears from them that:

$$0 \geq \Delta\theta(\bar{e}^{SB} - \underline{e}^{SB}) - \Delta y (p(\bar{e}^{SB}) - p(\underline{e}^{SB})).$$

By assumption $\Delta y > 0$, $p(\bar{e}^{SB}) - p(\underline{e}^{SB}) > 0$ because $\underline{e}^{SB} = \underline{e}^*$ hence $\Delta y (p(\bar{e}^{SB}) - p(\underline{e}^{SB})) > 0$ and $-(\Delta y (p(\bar{e}^{SB}) - p(\underline{e}^{SB}))) < 0$. Furthermore,

$\Delta\theta > 0$ and $\bar{e}^{SB} - e^{SB} < 0$, then the proposition is verified and we get the following relationship:

$$(23) \quad \underline{e}^* = \underline{e}^{SB} > \bar{e}^* > \bar{e}^{SB}.$$

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

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

then,

$$(24) \quad \underline{t}^{SB} - \underline{\theta}e - \underline{y}p(e) = \Delta\theta\bar{e}^{SB} - \Delta yp(\bar{e}^{SB}).$$

As a consequence:

$$(25) \quad \underline{t}^{SB} = \underline{\theta}e^* + \underline{y}p(e^*) + \Delta\theta\bar{e}^{SB} - \Delta yp(\bar{e}^{SB})$$

and,

$$(26) \quad \bar{t}^{SB} = \bar{\theta}\bar{e}^{SB} + \bar{y}p(\bar{e}^{SB}).$$

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

REMARK 1: It is legitimate to consider that $\Delta\theta = \bar{\theta} - \underline{\theta} > 0$, that expresses the difference in efficiency of agent $\underline{\theta}$ compared to agent $\bar{\theta}$ considering marginal costs. However, there is no economic legitimacy putting $\Delta y = \underline{y} - \bar{y} > 0$ (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: $p(e^*) > \left(1 - \frac{\bar{y}}{\underline{y}}\right)p(\bar{e}^{SB})$, with $1 > \frac{\bar{y}}{\underline{y}} > 0$ (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 $\frac{\bar{y}}{\underline{y}}p(\bar{e}^{SB})$. The demonstration of this remark is made in Appendix A4.

REMARK 3: Under a standard strict liability regime and asymmetric information, the efficient agents may be deterred to enter 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 $\frac{\bar{y}}{\underline{y}}p(\bar{e}^{SB})$.

This condition is particularly stringent because the efficient agent must know too much information before accepting the contract. Indeed, the efficient agent cannot know the nature of his opponent's wealth.

REMARK 4: The constraint [13a] ($\bar{U} \geq \underline{U} - \Delta\theta\underline{e} + \Delta yp(\underline{e})$) 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 reinforces 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 section 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 involvement 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:

$$(27) \quad C(e, \theta, y) = \theta e + Cp(e).$$

As previously, the informational rent expresses as:

$$(28) \quad \underline{U}^C = \underline{t} - c(\underline{\theta}, \underline{e}, \underline{y}) \geq \bar{t} - c(\underline{\theta}, \bar{e}, \underline{y})$$

and, processing as before when we got equation (18):

$$(29) \quad \underline{U}^C \geq \bar{U}^C + \Delta\theta\bar{e}$$

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

$$(30) \quad \bar{U}^C = \bar{t} - c(\bar{\theta}, \bar{e}, \bar{y}) \geq \underline{U}^C - \Delta\theta\bar{e}.$$

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

$$(31) \quad \text{Max}_{\{(\underline{U}^C, \underline{e}), (\bar{U}^C, \bar{e})\}} \vartheta \left(S(\underline{e}) - \underline{\theta}\underline{e} - Dp(\underline{e}) \right) + (1 - \vartheta) \left(S(\bar{e}) - \bar{\theta}\bar{e} - Dp(\bar{e}) \right) - \vartheta UC + 1 - \vartheta UC,$$

subject to the constraints:

$$(32) \quad \underline{U}^C \geq \bar{U}^C + \Delta\theta\bar{e}$$

$$(33) \quad \bar{U}^C \geq \underline{U}^C - \Delta\theta\bar{e}$$

$$(34) \quad \underline{U}^C \geq 0$$

$$(35) \quad \bar{U}^C \geq 0.$$

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. $\bar{e} > 0$. This is verified when the Inada condition $S'(0) \rightarrow +\infty$ is satisfied and $\lim_{e \rightarrow 0} S'(e) e = 0$. 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 to mimic 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 $\bar{\theta}$ -agent [35]. Getting the optimum of the PC program involves that both constraint must be binding:

$$(36) \quad \underline{U}^C \geq \Delta\theta\bar{e}$$

and,

$$(37) \quad \bar{U}^C = 0.$$

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

$$(38) \quad \text{Max}_{\{\underline{e}, \bar{e}\}} \vartheta \left(S(\underline{e}) - \underline{\theta}\underline{e} - Dp(\underline{e}) \right) + (1 - \vartheta) \left(S(\bar{e}) - \bar{\theta}\bar{e} - Dp(\bar{e}) \right) - \vartheta\Delta\theta\bar{e}.$$

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 is drawn the equilibrium values which are identical to the full information setting for the efficient agent.

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

and for the inefficient one:

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

It can be verified that with a similar argument made for the standard liability scheme can be defined the following relationship that follows from the monotony of the second-best schedule of safety level:

$$(41) \quad \underline{e}^* = \underline{e}^{SB} > \bar{e}^* > \bar{e}^{SB'}$$

(Where (" $\bar{e}^{SB'}$ ") stands for the second best under the capped regime). In summary, the following proposition can be deduced:

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 $\bar{\theta}$ type, gives:

$$S'(\bar{e}^{SB}) - \bar{\theta} = \frac{\vartheta}{(1-\vartheta)} \Delta\theta, \text{ with } \bar{e}^* > \bar{e}^{SB'}$$

- Only the efficient type gets a positive information rent given by:

$$(42) \quad \underline{U}^C = \Delta\theta\bar{e}$$

- The second best transfers are respectively:

$$(43) \quad \underline{t}^{SB} = \underline{\theta}e^* + Cp(\underline{e}^*) + \Delta\theta\bar{e}^{SB'}$$

And

$$(44) \quad \bar{t}^{SB} = \bar{\theta}\bar{e} + Cp(\bar{e}^{SB}).$$

The 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 under asymmetric information, putting caps on redress issues on the same level of effort than the standard strict liability regime under symmetric information. After this initial result, many avenues must be explored. For instance, the issue of insurance has not been addressed although it is an important matter for capped liability (SHAVELL [2005], (BOYD AND INGBERMAN [1997])). Subscribing policy insurance is compulsory for oil operators in the maritime sector and the nuclear industry. In this paper, the concern has been limited to the scope and power of an ex post regulatory control based on the ceiling of redress under informational asymmetries.

By ceiling the redress, the principal reduces the uncertainty involved by the unknown polluters' wealth. Furthermore, it can control the agents' activity by requiring that they have to own at least the amount of the cap as financial guarantee. This induces the withdrawal of the insufficient endowed agents. This can be achieved by resorting to insurance. For instance, if Q is that share which is insured, where:

$C - Q = w$ (with the share of the agent's wealth used as commitment). As a consequence, the agent has to cope with two principals: the RA and the insurance company. Indeed, 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 further research will have to develop these relationships.

5. Conclusion

Under asymmetric information, standard strict liability rules fail to provide the first best level of effort in safety. This favors adverse selection emergence and

can induce inefficient operators to undertake risky activities by deterring the efficient ones. Then, capping the level of redress can be an alternative to a standard strict liability regime. However, this switching does not guarantee automatically restoring efficiency. Indeed, some necessary conditions have to be fulfilled.

In real life, bounding the level of repairs raises strong opposition when people consider that the level of ceiling is too low. Consequently, under asymmetric information, the Principal has to formulate relevant contracts that make a tradeoff between the level of repairs and the 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 equilibrium, 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 mitigate the sharpness of 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. This 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 efficient agent in safety and avoids the adverse selection effect. This eviction effect of inefficient agent can be reinforced by the requirement of insurance policy that introduces a new principal in the scheme.

This paper brings a contribution to the debate about the reciprocal efficiency of capped or standard strict liability. It shows notably that under asymmetric information and a strict liability regime all opportunistic behavior can be adopted by inefficient operators and this leads to an inappropriate level of safety. Capping the level of redress induces to find again the care level of the symmetric information case under strict liability regime. The price to pay by the government is an information rent that can be minimized with an adequate level of transfer. This advocates for a generalization of strict liability with the capping of redresses as environmental policy. In the public's opinion, this choice could appear as counterintuitive because the level of redress is less than the damage involved by the harm. However, this solution means that the principal balances between the costs of improvement in safety and the costs of repairs and compensation. Furthermore, as in the nuclear industry, the level of the cap can be progressively raised. This involves to pool insurance companies and the deep-pocket lenders. This opens the debate on the other stream of the literature dedicated to the understanding of the judgment-proof question. This will constitute a further step in this research program.

Appendix

A.1 The welfare function of society:

$$\begin{aligned} W &= S(e)(1 - p(e)) + (S(e) - (D - K))p(e) - C(e) \Rightarrow \\ W &= S(e)(1 - p(e)) + (S(e) - (D - K))p(e) - \theta e - p(e)K = \\ W &= S(e) - \theta e - p(e)D \text{ for } \theta \in [\underline{\theta}, \bar{\theta}] \text{ and } K = \{C, y\}. \\ & \text{Q.E.D.} \end{aligned}$$

A.2. Proof of proposition 1

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

A.3. Proof of proposition 2

Hence, having $\underline{U} \geq 0$ [14'] cannot be considered as granted. Preliminary conditions have to be formulated. $\underline{U} \geq 0$ means that if $\bar{U} \geq 0$ is binding ($\bar{U} = 0$) then this involves that:

$\underline{U} = \Delta\theta\bar{e} - \Delta yp(\bar{e}) \geq 0$ or, still, $\Delta\theta/\Delta y \geq p(\bar{e})/\bar{e}$, by definition $p(\bar{e})/\bar{e} > 0$ (with $p(\bar{e})/\bar{e} \rightarrow 0$), furthermore, by definition, $\Delta\theta > 0$ then, the condition for having $\Delta\theta/\Delta y > 0$ is that $\Delta y > 0$ i.e. $\underline{y} > \bar{y}$ because $\Delta\theta > 0$. Hence, the condition for having $\underline{U} \geq 0$ is that $\underline{y} > \bar{y}$. That means that if the efficient agent is less rich than the inefficient one, then the participation constraint cannot be fulfilled.
 Q.E.D.

A.4. Proof of remark 2

Starting from

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

We study the conditions for which:

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

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

Getting the program

$Max_{\{(\underline{t}, \underline{e}), (\bar{t}, \bar{e})\}} \vartheta(S(e) - (D - C)p(\underline{e}) - \underline{t}) + (1 - \vartheta)(S(\bar{e}) - (D - C)p(\bar{e}) - \bar{t})$
 subject to the constraints of incentive compatibility:

$$\begin{aligned} \underline{t} - \underline{\theta e} - Cp(e) &\geq \bar{t} - \underline{\theta \bar{e}} - Cp(\bar{e}) \\ \bar{t} - c(\bar{\theta}, \bar{e}) &\geq \underline{t} - c(\bar{\theta}, \underline{e}) \end{aligned}$$

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

$$\begin{aligned} \underline{t} - \underline{\theta e} - Cp(\underline{e}) &\geq 0 \\ \bar{t} - \bar{\theta \bar{e}} - Cp(\bar{e}) &\geq 0. \end{aligned}$$

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

Q.E.D.

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G rard Mondello
University of Nice Sophia Antipolis,
Groupe de Recherche en Droit, Economie, Gestion (GREDEG), UMR 7321
Centre de recherche en droit  conomique (CREDECO),
Centre National de la Recherche Scientifique (CNRS).
250, rue Albert Einstein
06560 Valbonne Sophia Antipolis- France.
gerard.mondello@gredeg.cnrs.fr