TORT LAW UNDER OLIGOPOLISTIC COMPETITION

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Abstract: *This article extends the unilateral accident standard model to allow for Cournot competition. Assuming risk-neutrality for the regulator and injurers, it analyzes three liability regimes: strict liability, negligence rule, and strict liability with administrative authorization or permits systems. Under competition the equivalence between negligence rule and strict liability no longer holds, and negligence insures a better level of social care. However, enforcing both a permit system and strict liability restores equivalence between liability regimes. However, whatever the current regime, competition leads to lower the global safety level of industry. Indeed, the stronger firm may benefit from safety rents, which they may use to increase production rather that maintaining a high level of safety.*

Keywords: Tort Law; Strict Liability, Negligence rule, Imperfect Competition, Oligopoly, Cournot Competition.

JEL: D43, L13, L52, K13

Introduction

Stylized facts

On April 24, 2013, near Dhaka, Bangladesh, the Rana Plaza, a garment factory, abruptly collapsed: its owners illegally turned what was initially a residential house into a huge workshop. The accident caused the death of over a thousand workers and injured more than two thousands. This workspace operated as subcontractor for many well-known Western trade companies. By delocalizing their production there, these brands expected benefiting from some quadruple dumping: i) Low wages, ii) Weak payroll taxes, iii) Feeble corporate taxes and iv) Deficient environmental regulation. Enquiries showed that these firms triggered this disaster because of their seeking after trivial prevention costs. This case is far from being isolated. Indeed, the list of industrial, energy and agricultural sectors that neglect accident and environmental risks prevention is wide. Rather than giving an exhaustive inventory about technological disasters, we recall only two other emblematic cases. First, the 1984's chemical accident that Union Carbide Company caused in Bhopal (India)[1] and, second, the breakdown of the oil rig Deepwater Horizon leased by British Petroleum (20 April 2010 in the Gulf of Mexico). According to victims associations' assessment, the former, directly or indirectly, killed about 20,000 persons. The second catastrophe spawned a lower number of human victims but considerably polluted the US territorial waters. BP's activity consisted in reaching rich oil pockets in the deepest offshore well ever dug in the Gulf of Mexico. The legal investigations revealed significant deficiencies in the project securing[2]. In both cases, as in many others, underinvestment in safety or human errors caused these accidents.

Legal Liabilities as prevention instruments and the paper's object

Mass production generates large scale health violations and/or environment degradation as a byproduct. Reducing pollution and hazards involves pro-active policies by enforcing ex ante regulatory tools (rules, norms, standards), market instruments (taxes, emission permits) and ex-post liability regimes (administrative, civil and criminal laws).

Since the end of the 19th Century, as a consequence of the industrial revolution, tort law mainly expanded for compensating damage to third party on others. However, beyond compensation, Ronald Coase (1960) and Guido Calabresi (1961) (among many others) showed that enforcing effective tort law leads potential injurers to invest in safety for the

[1] Kleindorfer. and Kunreuther, (1987).

[2] See for instance the significant US Govern. Report (2011) part II.

purpose of avoiding oversized repairs[3]. Consequently, prevention costs become a strategic variable in the hands of facilities' managers on a par with production costs. Preventing damage requires significant investment. However, facing both constrained cash finance and competition, even wealthy big companies prefer earmarking financial resources for production rather than for safety when possible. Indeed, in the face of limited cash finance, the firms' managers have to mediate between financial assets dedicated to risk prevention and productive activities.

Considering this viewpoint, the present article introduces competition and production in the unilateral accident standard model that Brown (1973), Shavell (1980), 1987), Posner and Landes (1987) developed. The nodal model studies the behavior of a unique injurer (either an individual or a representative firm). However, in the light of the above two examples, the strategic interaction between competitors concerning what should be the effective care level needs some renewed attention. Thus, we model oligopolists playing a Cournot-Nash oligopoly game where care effort and quantities constitutes strategic variables. Firms are differentiated with respect to financial constraints. This extension requires modifying the standard model's two key assumptions. First, injurers' financial constraints differ from their assets value. The second assumption extends the standard model's scale of production. In this latter, production is fixed or associated to proportional scale increase. This involves that the injurers do not meet any financial constraint (see Appendix 1) and in this context, finance limitations come with the specific "judgment-proof" models[4].

In our model, injurers have limited financial means and, thus, they arbitrate between safety and production investments under a competitive environment. We keep the very standard assumption of risk-neutral agents (potential injurers and the regulator) and we analyze the consequences that this extension to competition has on care levels under different liability regimes.

Links to literature

Traditionally, introducing competitive market structures in the accident model is made by incorporating "product liability" in it. This literature is particularly abundant; Reinganum (2013) and Geistfeld (2009) review it. Pioneer authors are Epple, and Raviv (1978) who associated market structure with product liability. Besides, the interplay between industrial organization and liability received much less attention, however, than that between liability and innovation or insurance (Viscusi and Moore, 1991a,b; Viscusi and Moore, 1993). The

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[3]. See e.g. Cooter and Ulen (2003).
[4] See Shavell (1983), Sommer (1983).

most recent works (Baumann and Heine, 2012) combine competition, innovation and liability considering risky products. Our approach is closer to Spulber's (1989) who shows that the level of production of the firm can influence the investment costs related to prevention. For example, investments in prevention depend on the cross effect of these investments and the monopoly production costs. Thus, potential injurers in a very competitive market can offer products that are insufficiently secure.

The paper considers the basic accident model and the strategic behavior of potential injurers under oligopolistic competition ruled considering different liability regimes. We start from the basic accident model's assumption as defined by Calabresi (1970), Brown (1973) and especially Shavell (1980, 1982 1987b). However, we depart from this usual framework by introducing oligopolistic competition between several injurers. Harm does not only concern product quality but also workers' safety, environment, firms' vicinity.

A first section defines the model structure while a second one compares the injurers' behavior when competing in a duopoly framework and placed under three liability regimes: strict liability, negligence rule and strict liability coupled with permits or administrative authorization system. A third section studies a simplified duopoly system as an illustration and compares strict liability and negligence under the competitive framework. A fourth section concludes.

1. The model's structure

In accident models, civil liability imposes itself as a regulatory economic tool. This means that the socially first-best care level is an instrument that judges use in determining the injurers' liability. Indeed, this instrument becomes relevant only in case of dispute, mainly under negligence as Faure (2010) mentions it:

"*Under negligence, it is the judge who will determine the efficient care standard. Therefore, the judge will need further information on the costs of preventive measures and will have to weigh these against the probability that additional investments would reduce the expected damage. This will hence be translated in a due care standard to be followed by the potential injurer. Under negligence the injurer only needs information about the due care required but the court on the basis of case law*". *Faure (2010, p.20)*

So, if judge and regulator dispose both of equivalent calculation means and share the same rationality, then, they should determine an identical socially first-best care level for a given activity[5].

1.1 Assumptions and notations

A1. Potential injurers (also designed as tortfeasors, polluters or firms) are indexed by $i = 1, \ldots, I$, with I finite.

A2. Each agent i gets a loan Y_i at zero interest rate. Then, he dispatches Y_i by buying inputs for production (y_i) and inputs for care (x_i) such that:

$$y_i + x_i = Y_i \tag{1}$$

Each injurer i disposes of a non-monetary wealth u_i that consists in fixed assets.

A3. Production technology is identical across injurers. Let the production function be $\varphi(y_i): [0, Y_i] \rightarrow \mathbb{R}_+$ that obeys to concavity conditions $\varphi' > 0$, $\varphi'' \leq 0$, with $\varphi(0) = 0$ and $\varphi(Y_i) \equiv \bar{\varphi}_i$.

A4. x_i is the cost of care to firm i. An accident may occur with a probability $p(x_i)$, which is convex in x_i and $p'(x_i) < 0, p''(x_i) \geq 0)$ for all $x_i \in [0, Y_i]$. The no-accident probability is $1 - p(x_i)$, with $p(0) = 1$ and $\lim_{x_i \uparrow Y_i} p(x_i) = 0$[6].

A5. Total damage after a harm is d and damage per unit of output is $D > 1$. $d > 0$ if an accident occurs and 0 otherwise. The cost of harm is a function of d and production scale as follows: $h\big(d, \varphi(y_i)\big) = D\varphi(y_i)$[7]. Expected cost of harm is therefore $Dp(x_i)\varphi(y_i)$.

A6. u_i is higher than the maximum expected damage $u_i > D\,\varphi(Y_i)$.

A7. The inverse demand function is $\pi(\sum_{i=1}^{I} \varphi(y_i))$. It has the following properties $\pi' < 0$ and $\pi'' \geq 0$. Examples of demand functions that satisfy these properties include the affine and isoelastic demand functions.

A8. Firms make their production and investment decisions simultaneously and each knows the cost structures and the payoff function of its opponent. So, the game is of complete but imperfect information and competition is static (Tirole, 2007).

A9. Court and regulator perform the same assessment (see footnote 5).

[5] However, the court may feel difficulty in assessing the adequacy of the level of prevention and the level of activity (Shavell (1987), Shavell Polinsky (2005)).
[6] Implicitly, this assumption means that every injurer receives enough money to reduce risks to a zero level.
[7] See Dari-Mattiacci and De Geest (2005) for the technical questions about the damage scale.

1.2 Potential injurers' programs

Tort law literature focuses on the behavior of a single representative firm. However, considering oligopolistic competition makes more complex the injurers' strategic space. Oligopolistic competition involves strategic interactions between different decision-makers. In the short-term, the strategic variables are prices and quantities for given production cost structures while in longer terms, productive capacities and technologies may vary (Tirole (1988)). Here, besides price and quantities, the financially constrained injurers must choose between production and prevention effort. Generally under oligopolistic competition, firms are limited in capacity (production, finance etc.) or still by the financial loans they contract from finance suppliers (banks or financial markets). Indeed, production needs financial means to pay wages, buy intermediary products etc., and, in actual life these means are limited. This liquidity constraint differs from their illiquid assets.

The amount of finance the injurers get from the bank could be a function of their wealth u_i, that they partially use as a mortgage (u_i is an illiquid wealth that consists in physical and transferable assets). The higher u_i is, the higher the loan that the injurer can borrow. As mentioned in A.2, Y_i is allocated between funds y_i dedicated to purchasing inputs and funds x_i to meet the prevention cost, (equation (1)). The greater the care level, the less the quantity he can produce; the opposite holds.

Injurer's benefit function $\Pi_i(x_i, y_i, y_{-i})\colon \mathbb{R}_+ \times \mathbb{R}_+ \times \mathbb{R}_+ \to \mathbb{R}_+$ is

$$\Pi_i(x_i, y_i; y_{-i}) = \varphi(y_i)\pi\big(\varphi(y_i) + \textstyle\sum_{j\neq i}^{I} \varphi(y_j)\big) - x_i - y_i - d \tag{2}$$

Where d conforms to A5, consequently:

$$\Pi_i(x_i, y_i; y_{-i}) = \begin{cases} p(x_i)\left(\varphi(y_i)\pi\left(\varphi(y_i) + \displaystyle\sum_{j\neq i}^{I} \varphi(y_j)\right) - x_i - y_i\right) - p(x_i)D\varphi(y_i), & \text{(accident)} \\ \big(1 - p(x_i)\big)\left(\varphi(y_i)\pi\left(\varphi(y_i) + \displaystyle\sum_{j\neq i}^{I} \varphi(y_j)\right) - x_i - y_i\right) & \text{(no accident)} \end{cases} \tag{3}$$

The injurer's expected profit is therefore:

$$\mathbb{E}\left(\Pi_i\big(x_i, y_i; y_{-i}\big)\right) = \varphi(y_i)\pi\left(\varphi\big(y_i\big) + \textstyle\sum_{j\neq i}^{I} \varphi\left(y_j\right)\right) - x_i - y_i - p(x_i)D\,\varphi(y_i) \tag{4}$$

And his expected wealth is:

$$\mathbb{E}W\big(x_i, y_i; y_{-i}\big) = u_i + \mathbb{E}\Pi_i\big(x_i, y_i; y_{-i}\big) \tag{5}$$

Using equation (1) and rewriting (5) in terms of x_i and denoting $W(x_i, y_i; y_{-i})$ as $w(x_i; x_{-i})$, the injurer's expected wealth is:

$$\mathbb{E}\big(w(x_i;x_{-i})\big) = u_i + \varphi(Y_i - x_i)\pi\big(\varphi(Y_i - x_i) + \textstyle\sum_{j\neq i}^{I}\varphi\big(Y_j - x_j\big)\big) - Y_i - p(x_i)D\varphi(Y_i - x_i) \quad (6)$$

The injurer's program consists in finding x_i^*, such that:

$$x_i^* = \underset{x_i\geq 0}{\text{Argmax}}\, \mathbb{E}\big(w(x_i;x_{-i})\big) \quad (7)$$

The first order conditions do not issue on the standard model results (see appendix 1). Indeed, we cannot find any simple relationship between the damage and the level of care because of the introduction of production $\varphi(\cdot)$ and inverse demand $\pi(\cdot)$ (see Shavell 1987). However, the following proposition insures that an optimum level of care exists in the $[0, Y_i]$ interval.

Proposition 1: *On the interval $[0, Y_i]$ under the assumptions A1 to A9, an equilibrium value $(\varphi(y_i^*), x_i^*))$ exists, which respectively corresponds to injurer i's first-best levels of production and car,.*

Proof : see Appendix 2.

1.3 Regulation and financially constrained firms

In the standard accident model, the level of care that Society defines as necessary is calculated from the model's economic structure by minimizing the accident's social cost. However, in many sectors (e.g. chemical or energy industries) this calculus is not always feasible. Then the regulator can substitute to this economic value an administrative one based on scientific data for instance. This norm becomes mandatory for all injurers. In this section, we develop both concepts.

1.3.1 *The socially first-best care level*

As in the standard model[8], we can calculate the socially first best care level that minimizes the overall primary accident costs (i.e. the strict reparation costs, following Calabresi's view). Usually, authors consider that the regulator compares the performance of each liability regime and chooses the most efficient one. Consider $q_i := \varphi(y_i)$ the volume of production achieved by a potential injurer i. As the regulator can know the technology, he can calculate the production q_i for each level of input y_i. This technology is uniquely associated to a probability distribution that implicitly is common knowledge between the potential injurer and the regulator. The regulator's program is then:

$$\underset{x_i\geq 0}{\text{Min}}\{x_i + p(x_i)Dq_i,\ q_i \geq 0\} \quad (8)$$

[8] See Appendix 1 for a more complete analysis of the standard model with scale effect.

The set of solutions to the above program corresponds to the path $x_i^0(q_i)$ derived from the first-order condition (We call this value a "path" because it depends on the change in q_i):

$$p'(x_i) = -\frac{1}{Dq_i} \tag{9}$$

The cost of care $x_i^0(q_i)$ is an increasing function of q_i[9]. Starting from this result, the regulator sets out the "safety path" $x_i^0(q_i)$. We call this value a "path" because it depends on the change in q_i. This path is the socially first-best care frontier defined by the regulator.

Consequently, determining the "official" level of prevention that corresponds to the first best level of care $x_i^0(q_i)$ comes to define the necessary level of finance that the firm should dedicate to prevention. From the above considerations, it follows that when the regulator determines the optimal prevention path $x_i^0(q_i)$ for a given technology, he simultaneously determines the corresponding input level (or level of finance) y_i needed to achieve a production path $q_i = \varphi(y_i)$. More precisely, to the socially first best level of care $x_i^0(q_i^*)$ (corresponding to a corresponding volume of production q_i^*) must be associated the prevention level $x_i^0(q_i^*)$. Henceforth, to reach this goal, the firm needs the amount of finance y_i^* and, the theoretical funds necessary to reach the regulator's objectives is:

$$Y_i^0 = y_i^* + x_i^0(q_i^*) = y_i^* + x_i^0(\varphi(y_i^*)) \tag{10}$$

Obviously, Y_i^0 is only a theoretical value and corresponds to the amount that the potential injurer should get before producing to respect the socially first-best care level. Its value is not necessarily equal to the injurer's effective funding Y_i.

1.3.2 *The Socially Acceptable Risk Level (SARL)*

As in many models, one could assume a regulator who sets a safety floor so as to exclude firms that are too risky. This regulator would define a standard independent from economic considerations. For instance, regulatory nuclear agencies put standards on the reliability of nuclear reactors by defining an a priori probability of accident against the melting of the reactor's core. In the present model, the regulator sets the new prevention level

[9] Indeed, let consider two quantities $q_{i1} > q_{i2}$, then, $-\frac{1}{Dq_{i1}} > -\frac{1}{Dq_{i2}}$. Let x_{i1} and x_{i2} be the values associated to q_{i1} and q_{i2}, respectively, So, $p'(x_{i1}) > p'(x_{i2})$. But, p' is increasing by the assumption A4. Therefore $x_{i1} > x_{i2}$.

x^a and its corresponding accident probability $p(x^a)$. The couple $(x^a, p(x^a))$ is then so so-called Socially Acceptable Risk Level (SARL). Resorting to SARL rather than to the socially first best level of care is justified also by the fact that some time polluting emissions or certain risk thresholds are not determined endogenously but exogenously by strict scientific considerations. This is the case in the nuclear industry but also in the chemical industry for hazardous molecules. In models of these industries the SARL leads to determine the maximum level of production and the cost structure deduced from it:

$$x^a + p(x^a)D\, \varphi_k(y_i) = x^a + p(x^a)Dq_i \tag{11}$$

This cost varies as y_i changes. Here, the theoretical amount of the necessary funding that insures a safety level at least equal to $p(x^a)$ is such that:

$$Y_i^0 = y_i^* + x^a \geq Y_i \tag{12}$$

To summarize the above discussion:

- $x_i^0(q_i^*)$ corresponds to the socially first-best level of care that should be associated with the production level q_i^*. However, because, injurers are financially constrained, their optimal care level corresponding with q_i^* is x_i^*, where $x_i^* < x_i^0(q_i^*)$,
- x^a is a mandatory level, which the government sets simultaneously with p^a, the couple $(x^a, p(x^a))$ forms the SARL, independently from any economic consideration,
- x_i^* is firm i's first-best level of care.

1.4 The Decision tree

Competition between potential injurers is modeled as a Cournot-Nash oligopolistic game where the equilibrium price, production and level of safety are fixed simultaneously. The game has several stages:

Stage-1: The regulator enforces a specific civil liability rule to all firms.

Stage-2: Firms inform the regulator about the nature of their technology; the accident probability is common knowledge (see remark 1).

Stage-3: Firms simultaneously choose the optimal level of production and prevention that they will put into the market by maximizing their gain function given their budget constraint and the other players' offers.

Stage-4: The regulator either sets the equilibrium path of the socially optimal level of prevention $x_i^0(q_i)$ or, depending on the risk level of the activity, sets up the SARL $(x^a, p(x^a))$.

Step-5(a): No accident occurs, then, the firms realize their earnings and the game stops.

Step-5(b): An accident occurs and causes damage Dq_i^* (where q_i^* is the optimal level of production with the optimal level of input y_i^*).

Step-6(a): Under strict liability, the Court looks for the existence of a causal link between the firm's activity and the damage. If this link is positive, the judge determines the repair value (here it is assumed equal to the value of the damage) and sentences the injurer to repair.

Step-6(b): Under negligence, the Court gauges the relevancy of measures taken by the injurer relative to the social optimum care level. If the injurer has complied with the socially first best of care $(x_i^* \geq x_i^0(q_i^*))$ or, with the SARL $(x_i^* \geq x^a)$, then this one escapes from any liability. In the opposite case $(x_i^* < x_i^0(q_i^*))$, the judge will consider the injurer liable and this one will have to repair till Dq_i^*.

Remark 1: Step 2 is only justified in two cases. When the introduction of administrative authorization or permits associated with a liability rule is possible. The second case relates to a negligence rule. Indeed, the potential injurer disposes now of a standard that allows it to define a strategy specifically related to the rule of liability. In the standard model this assumption is implicit and never mentioned.

2. Equilibrium and liability regimes: a duopolistic model

We distinguish three situations. In the first one, the regulator enforces strict liability. In the second one, he resorts to negligence. In the third situation, he simultaneously enforces strict liability and an administrative authorization or permits system. Our aim is to study the consequences on the injurers' equilibrium strategic choices of safety and quantity under each regime.

2.1 Nash equilibrium under strict liability

What are the consequences of an accident occurrence under strict liability? There, the judge checks the existence of a causal link between the harm and the injurer's activity. If he proves this link, he indicts the injurer and forces him to pay for repairs. It results that, as he cannot escape liability, the potential injurer produces the level that maximizes his profit regardless of the socially first best level of care: the injurer follows his own interest independently from the regulator's view. We can verify this point by examining the equilibrium determination. Each firm maximizes its expected profit function under its budget constraint:

$$\underset{y_i,x_i}{\text{Max}}\, \mathbb{E}\big(\Pi_i(y_i, x_i; y_j, x_j)\big) = \varphi(y_i)\pi\left(\varphi(y_i) + \varphi(y_j)\right) - y_i - x_i - p(x_i)D\varphi(y_i), \qquad (13a)$$

Under the constraint:

$$Y_i = y_i + x_i;\ i, j = 1,2;\ i \neq j. \qquad (13b)$$

Budget constrained firms may only reach the socially first-best care level by chance. They dispose of enough wealth for repairing some major damages. Consequently, they produce and define their prevention level at the level that maximizes their expected payoff given the other competitor's supply. Then, assuming that they use fully their loan (13b is binding), the program simplifies by replacing x_i with $Y_i - x_i$, $i = 1,2$:

$$\underset{y_i}{Max}\, \mathbb{E}\big(\Pi_i(y_i; y_j)\big) = \varphi(y_i)\pi\left(\varphi(y_i) + \varphi(y_j)\right) - Y_i - p(Y_i - y_i)D\varphi(y_i) \qquad (14)$$

To each production level, given the opponent's one $\varphi(\overline{y_j})$ and for each best-response function $B_i(\overline{y_j})$, for $y_i{}^* \in B_i(y_j{}^*)$ and $i \neq j$ then the couple $(y_i{}^*, y_j{}^*)$ or, equivalently, $\left(\varphi(y_i^*), \overline{\varphi}(y_j^*)\right)$ is a Nash Equilibrium when it verifies:

$$\frac{\varphi'(y_i^*)}{\varphi(y_i^*)} + \frac{\pi'\left(\varphi(y_i^*) + \varphi(\overline{y_j})\right) + p'(Y_i - y_i^*)D}{\pi\left(\varphi(y_i^*) + \varphi(\overline{y_j})\right) - p(Y_i - y_i^*)D\varphi'(y_i^*)} = 0, i, j = 1,2 \qquad (15)$$

The optimal care level x_i^* can be deduced from $x_i^* = Y_i - y_i^*$. Consequently, without other institutional constraint than the strict liability enforcement, each firm determines both the first-best production and the care level $(\varphi(y_i^*),\ x_i^*)$, $i = 1,2$. Because the socially first-best level of care and the potential injurer's optimal prevention level are determined independently one from the other one, generally, they do not coincide. The potential injurer may over-invest in safety, $x_i^* > x_i^0\big(\varphi(y_i^*)\big) = x_i^0(q_i^*)$. He may instead under-invest since his objective is maximizing his profit and this consists in finding $(x_i^*, Y_i - x_i^*)$ given the other injurer's decision. This does not take account of the regulator's optimal prevention path, $x_i^0(q_i^*)$.

2.2 Nash equilibrium under negligence

Negligence leads to different behaviors compared to strict liability. Indeed, under negligence, if an injurer convinces the Court that he took enough care, then he escapes from any liability. Consequently, he keeps intact his wealth while, in the opposite case (liable), he loses it. Hence, if $x_i^* < x_i^0(q_i^*)$, the potential injurer disposes of three options:

- Option 1: The safety level that would exempt him of any liability is too high ($x_i^0(q_i^*) + y_i^* > Y_i$) compared to his budget. Thus, in case of an accident he incurs a loss of $\varphi(y_i^*)\pi(\varphi(y_i^*) + \overline{\varphi}(y_j{}^*)) - y_i^* - x_i^0(q_i^*) - D\varphi(y_i^*)$, which leads him to renounce to produce whereas his opponent enjoys a monopoly situation.
- Option 2: However, if the spread between x_i^* and $x_i^0(y_i^*)$ is not too large, the injurer could prefer to enforce $x_i^0(q_i)$ and reduce proportionally his production (thus, his profit). Obviously, this requires him solving the following program:

$$\max_{q_i \geq 0} \quad \mathbb{E}(\pi_i(q_i)) = q_i\pi(q_i + \bar{q}_j) - \varphi^{-1}(q_i) - x_i^0(q_i) - p\big(x_i^0(q_i)\big)Dq_i \tag{16a}$$

Under the constraint:

$$\varphi^{-1}(q_i) + x_i^0(q_i) = Y_i, i, j = 1,2, i \neq j \tag{16b}$$

$x_i^0(q_i)$ is the socially first best prevention path and $\varphi^{-1}(q_i) \coloneqq y_i$ is the reciprocal of the production function that gives the value of input y_j. In fact, if both firms are eager to comply with the regulator viewpoint, the above program applies to both. This means that the equilibrium production $q_i^* = \varphi(y_i^*)$ is such that:

$$\varphi^{-1}(q_i^*) + x_i^0(q_i^*) = y_i^* + x_i^0(q_i^*) = Y_i \tag{17}$$

Consequently, if this is how firms behave, then even if all agents (firms, regulator and judge) are risk neutral there is no chance of convergence between negligence and strict equilibrium case. Indeed, the potential injurer's program under negligence becomes for $i, j = 1,2, i \neq j$:

$$\begin{array}{c} q_i\pi\left(q_i + \overline{q_j}\right) - \varphi^{-1}(q_i) - x_i^0(q_i)\ if\ \ x_i^* \geq x_i^0(q_i^*)\ \ (a) \\ q_i\pi\left(q_i + \overline{q_j}\right) - \varphi^{-1}(q_i) - x_i^0(q_i) - p(x_i^0(q_i))Dq_i\ if\ \ x_i^* < x_i^0(q_i^*)\ \ (b) \end{array} \tag{18}$$

This last situation is not the rule and under some circumstances firms could compare the previous situation and that above.

- Option 3: Firms may prefer to take the risk of an accident after comparing $q_i\pi\big(q_i+\bar{q}_j\big)-\varphi^{-1}(q_i)-x_i^0(q_i)$ and $\mathbb{E}(\pi_i(y_i))$ for instance. Indeed, if $q_i\pi\big(q_i+\bar{q}_j\big)-\varphi^{-1}(q_i)-x_i^0(q_i)<\mathbb{E}(\pi_i(y_i))$ then a risk neutral agent may prefer to incur the risky situation, produce and sell $\varphi(y_i^*)$ rather than comply with the socially first best level of care.

The above argument shows that negligence directly influences the injurer's strategic behavior. This increases either the safety level by inducing the firm to comply with the socially first best of care or, following the demand's elasticity shape, to the *status quo*. This situation could also mean that the injurer accepts to behave similarly as under strict liability, thus the firm accepts to loose $\varphi(y_i^*)\pi\left(\varphi(y_i^*)+\varphi\big(y_j^*\big)\right)-y_i^*-x_i^*-D\varphi(y_i^*)$ in case of an accident.

2.3 Strict liability and administrative authorization

The regulator may consider that the effective prevention levels that potential injurers chose are too low compared to the socially first-best level. These firms present a risk profile higher than socially acceptable. Beyond the enforcement of strict liability, the regulator may remedy this through a permits or administrative authorization. To make the argument easier we consider that the reference risk is the SARL (x^a). In doing this, the regulator eliminates all firms that do not comply with the SARL and keeps safe the whole industry. Suppose we have the following situation:

$$x_2^*\geq x^a>x_1^*$$

This inequality means that firm-1 cannot fulfill the regulator's requirement. Consequently, it may exit the market for conditions that are explained below. To stay in the market the firm must dedicate $x^a-x_1^*$ of its financial resource to increase its prevention level. It results that the part devoted to production goes from $Y_1-x_1^*=y_1^*$ to $Y_1-x^a:=y_1^{*a}$. All things being equal, it follows that, the market supply becomes now:

$$\varphi(y_1^*-(x^a-\ x_1^*))+\varphi(y_2^*)<(\varphi(y_1^*)+\varphi(y_2^*)\ ) \tag{19}$$

Consequently, it results from this production decrease $(\varphi(Y_1-x_1^*)>\varphi(Y_1-x^a))$ that the price of the good increases if firm-2 keeps on producing $\varphi(y_2^*)$. Then,

$$\pi\big(\varphi(y_1^*-(x^a-\ x_1^*))+\varphi(y_2^*)\big)>\pi(\varphi(y_1^*)+\varphi(y_2^*)\ ) \tag{20}$$

Then, would it not be firm-2's interest to increase its production level in such a way that it could beneficiate from the price rise that follows firm-1's production's drop? Consequently, firm-2 follows the program:

$$\underset{y_2 \geq 0}{Max} \quad \mathbb{E}(H_2(y_2)) = \varphi(y_2)\pi\big(\varphi(y_2) + \varphi(y_1^{*a})\big) - Y_2 - p(Y_2 - y_2)D\varphi(y_2) \tag{21}$$

Under the constraint:

$$y_2 \leq Y_2 - x^a \tag{22}$$

Firm-2's best response may induce a corresponding increase in production in an amount equivalent to $\Delta\varphi(y_1^*) = \varphi(y_1^*) - \varphi(y_1^* - (x^a - x_1^*)) > 0$. Since firm-2 uses a larger portion of its loan Y_2 to produce, it therefore sacrifices part of its prevention level. If this production attaches to $\varphi(y_2^a) > \varphi(y_2^*)$, then the share of Y_2 devoted to prevention will proportionally be lower: $Y_2 - y_2^a = x_2^a$ where $x_2^* > x_2^a \geq x^a$ with, obviously $p(x_2^*) < p(x_2^a) \leq p(x^a)$. Then, what are the firm-2's incentives to increase its production level? In fact, these are related to the production function concavity. This point is the subject of the following proposition:

Proposition 2: *Under strict liability coupled with administrative authorization s, considering a Cournot duopolistic competition, if a given firm (here firm-1) does not fulfill the required level of prevention (here the SARL) x^a, i.e. if his optimal care level x_1^* is such that $(x^a > x_1^*)$, while firm-2 fulfils it $(x_2^* \geq x^a)$, then the economy knows the following potential conjunctures:*

1) *When firm-1 withdraws from the market, then firm-2 is in monopolistic position:*
   a. *. If both its production function and the demand function allow it, then firm-2's interest is to increase its production level from y_2^* to $y_2'^*$ (where $y_2'^* \geq y_2^*$) under the condition that the corresponding care level $x_2'^*$ (where $(x_2'^* \leq x_2^*)$ verifies $(x_2'^* \geq x^a)$.*
   b. *It results from above a. that comparing the firm-2's profit before and after the administrative authorization enforcement associated to x^a, the creation of a rent $R(\Delta y_2^*, \Delta x_2^*)$ where*

   $$R(\Delta y_2^*, \Delta x_2^*) = \mathbb{E}(\Pi_2(y'^*_2,\ x_2'^*)) - \mathbb{E}\big(\Pi_2(y_2^*,\ x_2^*)\big) > 0 \tag{23}$$

   This rent $R(\Delta y_2^*, \Delta x_2^*)$ comes from firm-2 monopoly situation and is called "safety rent". This involves that firm-2 decreases its safety level.
2) *Firm-1 stays on the market but potentially reduces its production level from $\varphi(y_1^*)$ to $\varphi(y_1^* - (x^a - x_1^*)$. This means, that firm-2 could increase its production level for $\varphi(y_2^*)$ to $\varphi(y_2^* + (x^a - x_1^*)$. Then, comparing the two situations as in 1, if it exists*

$R(\Delta y_2^*, \Delta x_2^*)$ defined as in 1.b and $R(\Delta y_2^*, \Delta x_2^*) > 0$ then firm-2 decreases its safety level to a value no less than x^a.

Proof (see Appendix 3)

Note that using the prevention rent by the unconstrained firm depends on many factors relating to its safety policy, the economic environment, the attitude of its customers against the risk, etc.

3. A simple illustration

Consider a duopoly, with $\varphi(y_1), \varphi(y_2)$ the quantities supplied by firm-1 and firm-2, which depend on y_i, $i = 1{,}2$, the parts of the credit Y_i dedicated to production costs. Production functions are linear and technologies identical: $\varphi(y_i) = ay_i$, $i = 1{,}2$. The inverse demand function is $\pi(\varphi(y_1) + \varphi(y_2)) = 1 - \varphi(y_1) + \varphi(y_2) = 1 - a(y_1 + y_2)$. We consider a linear probability of accident: $p(x_i) = 1 - x_i$ (see Hiriart and Martimort, 2006), then, we normalize the total costs as $x_i + y_i = Y_i \leq 1$. Furthermore, we assume that firm-2 gets a higher loan than firm 1: $Y_1 < Y_2$. After substituting $Y_i - y_i$ to x_i, firm i's problem is:

$$\underset{y_i > 0}{\text{Max}} \big(1 - a(y_i + y_j)\big)a\, y_i - Y_i - (1 - Y_i + y_i)Day_i, i = 1{,}2, i \neq j. \tag{24}$$

The Firm-i's best response is:

$$y_i = \frac{1-(1-Y_i)D-ay_j}{2(a+D)}. \tag{25}$$

The Cournot-Nash equilibrium solution (y_1^*, y_2^*) is given by:

$$y_1^* = \frac{2D(1 + D(-1 + Y_1)) + a(1 + D(-1 + 2Y_1 - Y_2))}{(a + 2D)(3a + 2D)} \tag{26}$$

$$y_2^* = \frac{2D(1 + D(-1 + Y_2)) + a(1 + D(-1 + 2Y_2 - Y_1))}{(a + 2D)(3a + 2D)} \tag{27}$$

It is easy to check that if $Y_1 < Y_2$ then $y_1^* < y_2^*$ and $x_1^* < x_2^*$; the better financially endowed firm produces more and provides a better prevention level[10].

3.1 Strict liability and permits

[10] Price is equal to $\pi\big(\varphi(y_1) + \varphi(y_2)\big) = 1 - a(y_1^* + y_2^*) = \frac{-2+3a-D(-4+Y_1+Y_2)}{3a+2D}$.

Suppose the regulator establishes a permit system where the permit to produce is given under the condition of regarding the given prevention level x^a such that ${x_2}^* > x^a > {x_1}^*$ and thus $p({x_2}^*) < p(x^a) < p({x_1}^*)$. Firm 1's maximum production level ${y_1}^a$ is immediately known: $a(Y_1 - x^a) = a{y_1}^a$, with ${y_1}^a < y_1^*$. Two options are then possible.

1) If x^a is such that $\mathbb{E}(\Pi_1({y_1}^a, y_2^*)) = (1 - a({y_1}^a - y_2^*))a\,{y_1}^a - {y_1}^a - x^a - (1 - x^a)D{q_1}^a < 0$, firm 1 renounces to produce and withdraws from the market. Consequently, firm 2 is in a monopoly position and uses:

$$y'^*_2 = \frac{1-D+DY_2}{2(a+D)} \tag{28}$$

Compared to the previous situation $y'^*_2 > y^*_2$. Indeed $y'^*_2 = y^*_2 + ay_1/2(a+D)$. We can easily see that Y_2 being given, the amount dedicated to safety is lower:

$$x_2{}'^* = Y_2 - y'^*_2 < x_2{}'^* = Y_2 - y^*_2 \; for \; x_2{}'^* \geq x^a \tag{29}$$

This example confirms the fact that enforcing both strict liability and a permit system leads to decrease the global risk by eliminating the more dangerous firms. However, the less risky one by increasing its production will decrease its formal safety level.

2) If $\mathbb{E}(\Pi_1({y_1}^a, y_2^*)) > 0$, firm-1 adapts to the SARL. It stays in the market but produces less; $a{y_1}^a$: $a{y_1}^a < a\,y_1^*$. The question that arises is to know what will be the response of firm-2? Will this one go on supplying q_2^* at the new price, which would insure a higher payoff, or will it increase its production. To answer to this question, we consider its best-response to ${y_1}^a = Y_1 - (x^a - {x_1}^*)$:

$$y_2^{*\prime} = \frac{1 - D + DY_2 - a{y_1}^a}{2(a+D)} = \frac{1 - D + DY_2 - a(Y_1 - (x^a - {x_1}^*))}{2(a+D)}$$

One may verify that $y_2^{*\prime} > y_2^*$. Besides, as firm-2 increases its production it diminishes its prevention expenditures, $x_2^{*\prime} = Y_2 - y_2^{*\prime} = {x_2}^{*\prime} < {x_2}^*$ and this illustrates proposition 3. Thus, the Cournot-Nash solution under a permit system and the enforcement of strict liability may push the weakest companies to resign or to increase their safety level. Regarding the stronger company, it may be induced to decrease its safety level to meet the new requirement of demand.

3.2 Duopoly and negligence rule.

Here, under negligence the regulator defines the SARL x^a. Let us assume that ${x_2}^* > x^a > {x_1}^*$ or equivalently, $p({x_2}^*) < p(x^a) < p({x_1}^*)$. Compared to the previous situation, firm 1 disposes of several choices. First, it may prefer not being involved in liability and exit from the market. Second, it may increase the safety investment to x^a instead of $x_1{}^*$ to comply with the SARL. Third, as already mentioned, the firm may stay in the market running the risk to pay for repairs in case of an accident. The first two cases are similar to the section 3.1 case and they receive the same analysis. The third case, however (producing with a socially non-optimal care level) requires a different analysis.

In spite of the threat of paying the total amount of repairs Day_1^*, firm-1 could be induced producing as long as the Cournot-Nash solution (q_1^*, q_2^*) satisfies $\pi^* a y_1^* - Y_1 - (1 - x_1^*) D\ a\ y_1^* > 0$, with $\pi^* = 1 - a(y_1^* + y_2^*)$. Or, equivalently,

$$\pi^* > \frac{Y_1}{a y_1^*} + (1 - x_1^*) D$$

If this relation is verified, firm-1 expects a benefit and it keeps on producing rather than withdrawing from the market in spite of its possible liability involvement in case of an accident. Let us consider now firm-2's choice under negligence. If $x_2 \geq x^a$ (case a) it gets the following payoff $\pi^* a y_2^* - Y_2$, for, it gets rid of any liability. In the opposite situation, $x_2 < x^a$ (case b) its expected payoff becomes $\pi^* a y_2^* - Y_2 - (1 - x_2^*) D a y_2^*$. The similarity with the immediate above situation should not lead to perfectly assimilate both cases. Indeed, here, the case b does not mean that firm-2 withdraws. Indeed, like firm-1, if:

$$\pi^* > \frac{Y_2}{a y_2^*} + (1 - x_2^*) D,$$

Then, firm-2 may choose to produce on a larger scale. Note that different Nash *equilibria* depend on the behavior of firm-1 facing x^a. In fact, the enforcement of negligence with a given SARL leads to different behaviors that the following table helps understanding. In this table each column corresponds to a specific Nash equilibrium.

Nash Equilibria	(1) $(a\ y_1^*, a\ y_2^*)$	(2) $(a y_1^a, a y_2^*)$ $y_1^a < y_1^*$	(3) $(a y_1^a, a y_2^f)$ $y_2^f > y_2^*$	(4) $(0, a\ y_2^{*\prime})$
Prevention level of firm 1	$x^a > x_1{}^*$	x^a	x^a	Firm 1 quits
Prevention level of firm 2	$x_2{}^* > x^a$	$x_2{}^* > x^a$	$x_2{}^* > x_2{}^f$ (*)	$x_2{}^* > x_2{}^f \geq x^a$ (*)
Accident consequences	Firm 1 supports the loss: $Y_1 - (1 - x_1^*) D\ a\ y_1^*$	Each firm complies with the SARL.	Firm 1 complies with the SARL and firm 2 increases its production	Firm 2 extends its production and decreases its safety level.

			volume	

Table 1: Cournot-Nash recension under the Rule of Negligence

((*)For $\pi^* > \frac{Y_2}{ay_2^f} + (1 - x_2{}^f)Day_2^f, y_2^a > y_2^f > y_2^*$) where, respectively, $y_2^f \in [y_1^a, y_2{}^*]$ and $x_2^f \in [x_1^a, x_2{}^*]$).

We explain now the different cases of table 1.

(1) The Nash equilibrium is similar to the one that reached under strict liability. Firm-1 chooses producing despite the introduction of negligence. This choice is allowed only if $\pi^* > \frac{Y_1}{ay_1^*} + (1 - x_1^*)D$.

(2) To achieve the standard x^a and avoiding any liability in case of an accident, firm-1 reduces its production. Firm-2 maintains the same levels of production and protection. As the global production decreases, (ay_1^a, ay_2^*) is a non-stable Nash-Equilibrium because, firm-2 has to react to this new situation.

(3) (ay_1^a, ay_2^f) is a Nash equilibrium that results for the simultaneous adjustment of firm 1 and 2 because of the enforcement of negligence. Here, the effort of prevention may be, for firm-2, below the one required as SARL. Firm-2 may decide to produce beyond in so far that $\pi^* > \frac{Y_2}{ay_2^f} + (1 - x^f)Day_2^f$.

(4) In situation 4, firm-1 decides withdrawing. Firm-2 is found in the same situation as before. It may produce as long as $\pi^* > \frac{Y_2}{ay_2^f} + (1 - x^f)Day_2^f$.

Oligopolistic competition as characterized in this article makes difficult comparing negligence and strict liability. However, it appears that negligence rule seems more care incentive than strict liability when this last one is not accompanied by an authorization system (permits or administrative authorization). In this case, unlike the negligence, strict liability can limit market access to firms that do not meet the required level of prevention (first best level of care or SARL). However, any administrative exclusion does not exist with negligence because, if ultra-hazardous companies consider that the expected cost of the damage is lower than their earnings, they may stop producing. A clear comparison between regimes should then involve a better knowledge of the industrial sectors. Indeed, some of them may accept a lowering of safety of financially unconstrained firms, while others do not allow it because among other, competition may bear on the safety level.

4. Conclusion

Introducing competition into the basic unilateral accident model opens a rich panel of situations that deserve attention. First of all, this extension does not lead to the classical results for risk neutral agents as, for instance, the equivalence in care efficiency between strict liability and negligence. Indeed, each regime defines a specific socially first best care level. Furthermore, our approach aims at understanding how injurers behave under competition within the standard unilateral accident pattern. We consider risky firms included in a duopoly competition. Their fixed assets are sufficient to absorb potential repairs due to harm that they cause; however, these corporates are financially constrained in term of cash money. This dual situation is not contradictory because, most of the time, their non-current assets value is higher than their financial credit. Consequently, these firms must constantly mediate between safety/security and productive investments.

Facing high risks, the rule of negligence leads the riskiest companies to follow cautious behavior by encouraging them either to comply with the socially first best level of care or to withdraw from the market. However, depending on the demand elasticity and/or the company's wealth level (different from its financing constraints), these companies can accept to run the risk of an accident, this, just as well as if strict liability was enforced. Under this latter regime, the injurer has no incentive complying with the socially first best care level. Therefore, he chooses the care effort that maximizes its profit given the other competitor's supply. However, the model shows that both regimes may coincide if the authorities match the strict liability with an authorization system. This leads eliminating the riskiest companies. This stems from the fact that, under a duopoly, the weakest company chooses either to withdraw from the market or to increase its care level to comply with the social standard and, consequently to decrease its equilibrium supply.

When the firm leaves the market, the remaining one is clearly a monopoly and behaves as such. Consequently, the remaining injurer may increase its supply but at the price of decreasing safety because of its financial constraint. We have to note that the stronger firm could prefer to maintain a higher level of safety by supplying the same amount of good, then, this one beneficiates from an increase in prices. This depends on the demand elasticity and the will of the firm governance to benefit from the safety rent.

To conclude, when polluters are in a competitive situation, enforcing liability rules do not automatically increases safety. In certain circumstances, the liability rule may induce the richest companies to increase their production (in so far to compensate for shrinkage or the slightest offer of the lowest businesses). The premium that this article seems to give to negligence rule must be balanced by the fact that proving evidence of fault or negligence involves huge transaction costs borne by the victims. This may hugely increases the social cost. This point, which we did not address in the model, provides a track for future research. Another avenue to explore lies in the differentiation induced by technology and R & D.

Appendix 1
The standard model: scale of activity vs. production

This appendix introduces the standard form of the unilateral accident framework with production, but in which potential injurers are not financially constrained. Early models date back to Brown (1973), Landes and Posner (1987) and Shavell (1987, 2007). In these models the potential injurer determines the optimal level of production before the optimal level of prevention. This latter is the level that minimizes the expected cost of primary accident $x + p(x)D$ (the expected value of prevention means plus repairs or damage value). Assuming that G represents the gain (a given value) in the profit function, the injurer's program (similarly for the regulator) consists in finding the non-negative x that maximizes the gain (or profit) net of the expected cost of a primary accident, $\Pi(x) = G - x - p(x)D$. In the case of a unilateral accident, potential victims are not involved in the prevention process; thus, G disappears and the socially optimal prevention level is deduced from the first order condition

$$p'(x) = -\frac{1}{D} \tag{A1.1}$$

The first-best level of care $x^0(D)$ increases with D (Shavell, 1984); see also section 1.3 in the present paper.

An implicit assumption is that the extent of damage is associated with the scale of activity, which leads to different scenarios regarding both regimes of responsibility for prevention: "Now let us reconsider unilateral accidents, allowing for injurers to choose their level of activity z, which is interpreted as the (continuously variable) number of times they engage in their activity (or if injurers are firms, the scale of their output)" (Kaplow and Shavell, 2002, p. 1670). Let us denote expected profit as $\pi(z, x) = g(z) - z\,x - z\,p(x)D$, with z the scale of activity, $g(z)$ the gain of the activity; see Shavell (1987, 2004) and Shafer and Shonenberger (1999, p. 602-603). The program is to solve

$$\{z^0, x^0\} = \underset{z,x}{\operatorname{argm}ax}\, \pi(z, x), \qquad \text{(A1.2)},$$

for non-negative values of z and x. Unless z is equal to 0 it plays no role in the determination of x^0; indeed, the FOC for x is $z\big(1 + D\,p'(x^0)\big) = 0$, which is equivalent to (A1.1).

Regarding z^0, it is determined by the FOC $g'(z^0) = x^0 + p(x^0)D$, that is marginal gain from the activity equals the expected optimal social cost of an accident.

Under strict liability, whereby liability is imposed on a party without a finding of fault (e.g. negligence or tortious intent), the potential injurer complies with the socially first-best level of care. The rationale for this is that damage payment will be D whenever the harm occurs. Under negligence, which occurs when injurers fail in exercising the care that a cautious and rational persons would exercise in like circumstances, the harm is due to lack of care without intentional harm. In case of an accident, if the indicted injurer can show that he exercised due care (he supplied x^0), then it can escape from any liability. Nonetheless, the injurer may be tempted to increase his scale of activity beyond z^0, which is reinforced by the fact that, hardly, Courts can define what should be a right scale level (Kaplow and Shavell, 2002; Shavell; 1987).

As shown above, A1.2 leads to FOCs that completely dissociates the determination of optimal prevention x^0 from that of z^0 (the opposite is not true), although by assumption that the expected cost of an accident increases with the scale of activity. Furthermore, the effective needed level of finance is fixed once determined the specific requirements for scale production and for prevention. Therefore, there is no financial constraint on the part of the potential injurer who does not to have to substitute safety for production. The introduction of a budget constraint changes the usual representation of a dissociated determination of the needs for prevention that leads to determine x^0 independently from z^0.

Appendix 2
Proof of proposition 1

Replacing x_i with $Y_i - y_i$ in $W(x_i, y_i; y_{-i})$, we obtain:

$$\mathbb{E}(W(Y_i - y_i, y_i; \bar{y}_{-i})) = A + \varphi(y_i)[\pi(\varphi(y_i) + \textstyle\sum_{j\neq i}^{I} \varphi(\bar{y}_j)) - p(Y_i - y_i)D], \qquad \text{(A2.1)}$$

with $A := u_i - Y_i$, $\bar{y}_{-i} = (\bar{y}_1, \dots, \bar{y}_{i-1}, \bar{y}_{i+1}, \dots, \bar{y}_I)$. A and $\sum_{j\neq i}^{I} \varphi(\bar{y}_j)$ are given. We define $\mathbb{E}(W(Y_i - y_i, y_i; \bar{y}_{-i}))$ as $H(y_i)$.

From assumption A4 and A7, $p(Y_i - y_i)$ increases and $\pi(\varphi(y_i) + \sum_{j\neq i}^{I} \varphi(\bar{y}_j))$ decreases as y_i increases in the interval $[0, Y_i]$. Let's assume that $\pi(\varphi(y_i) + \sum_{j\neq i}^{I} \varphi(\bar{y}_j))$ and $p(Y_i - y_i)D$ cross once in that interval; thus, there exists $\tilde{y}_i \in [0, Y_i]$ such that $\pi(\varphi(\tilde{y}_i) + \sum_{j\neq i}^{I} \varphi(\bar{y}_j)) -$

$p(Y_i - \tilde{y}_i)D = 0$. This implies that $H(0) = H(\tilde{y}_i) = A > H(Y_i)$. Therefore, from Rolle theorem there exists $y_i^* \in (0, \tilde{y}_i)$ such that $H'(y_i^*) = 0$, with

$$H'(y_i) = \varphi'(\pi - pD) + \varphi(\pi'\varphi' + Dp'). \quad \text{(A2.2)}$$

Note that $H'(0) = \varphi'\pi > 0$ and $H'(\tilde{y}_i) = \varphi(\pi'\varphi' + Dp') < 0$. Taking the derivative of A2.2 and replacing $\pi'\varphi' + Dp'$ with its expression derived from the first order condition $H'(y_i) = 0$, we obtain

$$H''(y_i^*) = [\varphi'' - 2(\varphi')^2/\varphi](\pi - pD) + \varphi\left(\pi''(\varphi')^2 + \pi'(\varphi'')^2 - Dp''\right). \quad \text{(A2.3)}$$

$(\pi - pD)$ is positive since $y_i^* < \tilde{y}_i$ and φ'' is negative since φ is concave; thus the first element is negative. The sign of $\pi''(\varphi')^2 + \pi'(\varphi'')^2 - Dp''$ is the same as that of $\pi'(\varphi'')^2 - Dp''$ in the case of an affine demand function ($\pi'' = 0$ is not excluded from assumption A7). But, $p'' > 0$. Consequently $\pi'(\varphi'')^2 - Dp'' < 0$ and therefore $H''(y_i^*) < 0$.

Proof of proposition 2

The proof relies on the following arguments:

1.a) When firm 1 withdraws from the market, firm 2 becomes a monopoly and the new price and expected profit functions respectively become $\pi(\varphi(y_2))$ and $\varphi(y_2)\pi(\varphi(y_2)) - y_2 - x_2 - p(x_2)D\varphi(y_2)$. Substituting $Y_2 - y_2$ to x_2, the firm 2's program writes as:

$$\underset{y_2 \geq 0}{Max}\, \mathbb{E}(\Pi_2(y_2)) = \{\varphi(y_2)\pi(\varphi(y_2)) - Y_2 - p(Y_2 - y_2)D\varphi(y_2)\} \quad \text{(A2.4)}$$

Depending on the shape of its production function and on its financial constraint, firm 2 may find interesting to supply at least at the firm-1's level (i.e. the one before the social norm enforcement). Thus, the production range is:

$$T = [\varphi(y_2^*), \varphi(y_2^*) + \varphi(y_1^*)] \quad \text{(A2.5)}$$

If the equilibrium quantity as monopoly $\varphi(y'^*_2)$ lies in T, then $\mathbb{E}(\Pi_2(y'^*_2)) \geq \mathbb{E}(\Pi_2(y_2^*))$ and the resulting safety rent is $R(\Delta y_2^*) = \mathbb{E}(\Pi_2(y'^*_2)) - \mathbb{E}(\Pi_2(y_2^*)) \geq 0$. This proves the first part of the proposition. We notice that this result is true provided that y'^*_2 belongs to the increasing return zone of the production function. The necessary equilibrium value for input will be $y_2'^* > y_2^*$ for $R(\Delta y_2^*) > 0$.

1.b) Obviously, since $Y_2 = y_2 + x_2$ is the budget constraint and Y_2 is given, then, $y_2'^* > y_2^*$involves that $x_2'^* < x_2^*$.

2) Let us consider firm 2, knowing that firm 1 is constrained. Its budget constraint becomes $Y_1 - x_1^a = y_1^a$ with $y_1^a < y_1^*$. The market price will rise to $\pi\big(\varphi(y_1^a) + \varphi(y_2^*)\big) > \pi\big(\varphi(y_1^*) + \varphi(y_2^*)\big)$. If $\varphi(.)$, a concave function, increases as y_2 varies from y_2^* to $y_2^{*\prime}$, this means that these values are located in the decreasing returns zone of φ (recall that y_2^* is the quantity supplied by firm 2 when firm 1 is not constrained). Consequently, $y_2^{*\prime}$ is the value for which, either:

- $Y_2 - y_2^{*\prime} = x^a$. Going farther would mean that the firm is not be allowed to produce.

- Or, $Y_2 - y_2^{*'} < x^a$, then $Y_2 - x^a$ is located in the decreasing return zone.

3) The second part of the proof is similar to 1.b above.

5. Bibliography

Baumann, F., Heine, K. (2012). "Innovation, tort law, and competition", *Dice Discussion Paper,* Heinrich-Heine-Universität Düsseldorf, 78.

Beard, T. (1990). "Bankruptcy and care choice", *Rand Journal of Economics* 21: 626-634.

Boyd, J. (1994). "Risk, liability, and monopoly", *International Journal of the Economics of Business* 1: 387-403.

Brown, J. (1973). "Toward an economic theory of liability", *Journal of Legal Studies*, 2: 323-349.

Calabresi, G. (1961). "Some thoughts on risk distributions and the law of torts", *Faculty Scholarship Series*. Paper 1979. http://digitalcommons.law.yale.edu/fss_papers/1979

Calabresi, G. (1970). *The Costs of Accidents, a Legal and Economic Analysis*. New Haven. Yale University Press.

Coase, R. (1960). "The problem of social cost", *Journal of Law and Economics* 22: 141-162.

Cooter, R., Ulen, T. (2003). *Law and Economics*, 4th Ed. Reading, MA: Pearson Addison Wesley.

Dari-Mattiacci, G., De Geest, G. (2005). "Judgment proofness under four different precaution technologies", *Journal of Institutional and Theoretical Economics* 161: 38-56.

Daughety, A.F., Reinganum, J.F. (2013). "Economic analysis of products liability: theory". In: Arlen, J.H., *Research Handbook on the Economics of Torts*, Edward Elgar: 69-96.

Epple, D., Raviv, A. (1978). "Product safety: liability rules, market structure, and imperfect information". *The American Economic Review* 68: 80–95.

Faure, M.G. (2010). "Behavioural accident law and economics", *Journal of Applied Economy* 12: 11-69.

Geistfeld, M. (2009). "Products liability". In: Faure, M., *Tort Law and Economics*, Edward Elgar.

Hiriart, Y., Martimort, D. (2006). "The benefits of extended liability", *The RAND Journal of Economics* 37: 562-582.

Kaplow, L., Shavell, S. (2002). "Economic analysis of law". In *Handbook of Public Economics* 3: 1663-1784, Auerbach, A.J., Feldstein, M. (Eds).

Kleindorfer. P.R. and Kunreuther, H.C. (1987). *Insuring and Managing Hazardous Risks: from Seveso to Bhopal and Beyond*. Springer, New York.

Kolstad, C.D., Ulen, T.S., Johnson, G.V. (1990). "*Ex post* liability for harm vs. *ex ante* safety regulation: substitutes or complements?", *The American Economic Review* 80: 888-901.

Micelli, T.J. (1997). *Economics of the Law*. Oxford University Press.

Steven, S. (1980). "Strict liability versus negligence", *Journal of Legal Studies* 9: 1-25.

Shavell, S. (1986). "The judgment proof problem", *International Review of Law and Economics* 6: 45-58.

Shavell, S. (1987). *Economic Analysis of Accident law*. Harvard University Press.

Shavell, S. (2004). *Foundations of Economic Analysis of Law*. Harvard University Press.

Schafer, Hans Bernd and Andreas Shonenberger (1999), Strict Liability Versus Negligence, in the Encyclopedia of Law and Economics.

Spulber, D.F. (1989). *Regulation and Markets*, Cambridge, MA: MIT Press.

US Government (2011). "Deep water: the Gulf oil disaster and the future of offshore drilling", Report to the President (BP Oil Spill Commission Report), https://www.gpo.gov/fdsys/pkg/GPO-OILCOMMISSION/content-detail.html

Viscusi, W.K., Moore, M.J. (1991a). "Rationalizing the relationship between product liability and innovation". In Schuck, P.H. (Ed). *Tort Law and the Public Interest:*

Competition, Innovation, and Consumer Welfare, New York: W.W. Norton & Co.: 105-26.

Viscusi, W.K., Moore, M.J. (1991b). "An industrial profile of the links between product liability and innovation". In Huber, P.W., Litan, R.E. (Eds). *The Liability Maze: The Impact of Liability Law on Safety and Innovation*, Washington, DC: The Brookings Institution: 81-119.

Viscusi, W., Moore, M. (1993). "Product liability, research and development, and innovation", *Journal of Political Economy*, 101: 161-84.

Tirole, J. (1988). *The Theory of Industrial Organization*, MIT Press.

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