Prevention, Limited Liability and Market Structure

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Paper prepared for presentation at the Xth EAAE Congress
‘Exploring Diversity in the European Agri-Food System’,
Zaragoza (Spain), 28-31 August 2002

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January 31, 2002

Abstract

Under a market setting, we analyse the impact of legal liability on prevention, taking into account the possible limited wealth of firms. We show that under strict liability, firms may choose ex ante not to be able to fully indemnify victims ex post: whatever the market structure, they may use limited liability strategically by investing in prevention in excess of what is socially optimal. The negligence rule prevents firms from over-investment. For high levels of damages, under both liability rules, firms exert an insufficient effort of prevention. A welfare analysis establishes that when the judgment proof problem is acute, the optimal public intervention ranges from banning the production to imposing the negligence rule.

1 Introduction

Litigation as a tool to manage external risks, such as environmental risks, has been a common practice in the US since the 1980s (see for instance the CERCLA, Comprehensive Environmental Response Compensation and Liability Act) and is under scrutiny by the European Commission (EC, 2000). Legal liability for damages generally has two goals: providing compensation to victims and limiting risks by creating incentives for lowering the probability and/or the severity of accidents. With respect to compensation, legal liability faces the issue of the “judgement proof” injurer that is an injurer unable to pay some portion of the losses to victims. The fact that a potential injurer’s liability is bounded by its wealth and the doctrine of limited liability, by reinforcing the externality, has implications on the prevention activity (Shavell, 1986).

Many prevention efforts require better equipment. Modified plants can be costly. For instance, prevention efforts by industrial firms or farmers for reducing water pollution in rivers are very difficult to implement, even in developed countries, mainly because of the prohibitive costs (Dinar and Zilberman, 1991). Firms do invest in prevention if their expected profits are high enough. Florida
and Davison (2001) show that the voluntary adoption of environmental management systems is associated with factories that are relatively large.

Furthermore, the costly prevention activity may dramatically reduce the available funds for indemnification in case of a damage. Victims compensation can also be limited due to the small size of involved producers. By the same token, the delegation of risky activities from big firms to small and medium firms with a pronounced limited liability weakens the effectiveness of any legal liability regime. Eventually, liability really threatens and influences the strategies of large firms. For instance, Aventis recently sold its share of Aventis CropScience to Bayer partly due to pending liability payments because of the new StarLink maize, a genetically modified organism (GMO) case (Financial Times, 2001). Traces of the GMO were found in processed foods, which costs may force Aventis CropScience to compensate farmers and manufacturers up to $200 millions in the USA. Aventis faced too many financial difficulties after the resulting withdrawal of the StarLink maize (EPA, 2000).

In this paper, we investigate the efficiency of legal liability, combining insolvency considerations with different market structure configurations. The relationships between liability and insolvency on one hand, and liability and market structure on the other hand, have been treated in previous research, but none has investigated the role of market structure on prevention efforts under polluters’ potential insolvency.

In one strand of the literature, the issue associated with insolvency assumes that the firm’s net worth is exogenous without any reference to competition. It underlines how incentives to invest in prevention may be diluted. Summers (1983) and Shavell (1987) show that under different liability rules, potentially insolvent parties exert an effort lower than the socially optimal level since they care only about the costs they might actually have to pay. In contrast, Lipowsky-Posey (1993) and Beard (1990) show that, considering a strict liability rule, potentially insolvent injurers might overinvest in prevention. Since the firm’s wealth is exogenous, they cannot question whether the overinvestment in prevention is desirable from a social point of view. Finally, for some other authors, the judgment proof problem is considered as exogenous (cf. for example Watts, 1998). The second strand of the literature encompasses research focused on liability rules in a market setting, such as Polinsky (1980), Epple and Raviv (1978), Polinsky and Rogerson (1983) and more recently Hamilton (1998) and Hamilton and Sunding (2000). In this research where the assets of the potential injurer come from a market interaction, the judgment proof problem is neglected favoring the competition intensity and/or the firms’ entry aspects. Another strand of literature related to our paper tackles the question of the firm’s financial structure with respect to the prevention activity (cf. van’t Veld et al., 1997, Fees and Hege, 1999a, and Dionne and Spaeter, 2001 for recent contributions). Among others, the liability rules influence the firms’ decisions regarding the equity-debt ratio and generally require the use of extended liability to banks. In our paper, the proﬁt is the only source of wealth, enabling us to focus on market structure.

We propose an analysis of firms’ incentives to invest in prevention under alternative public regulations, in a case of external damages. An efficient reg-
ulation needs to carefully consider the following aspects. First, the prevention activity affects ...rms’ pro...ts: A higher e...ort reduces the probability of an accident and the pro...ts that are available to pay damages; thus, higher e...ort increases the probability of being judgment proof. Second, ...rms’ pro...ts are affected by the market structure: The more concentrated the market, the higher the pro...ts and the higher the assets available for indemnification; higher pro...ts reduces the probability of being judgment proof.

Compared to previous approaches, we give a unified framework for studying the impact of legal liability on prevention, enabling to emphasize the strategic use of insolvency by ...rms. We propose a complete characterization of ...rms’ and regulator’s decisions. Additionally, we take into account the extent of damage, the consumers’ willingness to pay and the number of active ...rms.

We show that whatever the market structure, under alternative liability rules, the private optimal level of e...ort depends on the perspective of pro...ts and more precisely on the maximum willingness to pay for consumers with respect to the magnitude of external damages. For certain parameter values, incentives to invest in prevention are diluted: under strict liability where the injurer is liable regardless of his e...ort, ...rms either underinvest or overinvest in prevention. The overinvestment in prevention appears as a pernicious effect of liability under potential insolvency: It is the result of the strategic use of the limited wealth and limited liability by ...rms. It can be corrected with the negligence rule under which the injurer is liable only if the level of “due care” is not taken.

A welfare analysis exhibits that whatever the number of ...rms, the optimal public intervention ranges from banning the production (or equivalently product withdrawal of the market) to imposing the negligence rule. Implementing the socially optimal public intervention requires a precise evaluation of some relevant parameters, as the extent of the damage, consumers’ maximum willingness to pay and market structure. This suggests that different types of pollution may not be submitted to the same regulation.

The model is presented in section 2. Section 3 describes the ...rms’ optimal strategies under different legal environments. A comparative static analysis is then proposed for addressing the question of the impact of market structure on prevention. The welfare analysis is presented in section 4. Section 5 concludes.

2 The Model

We consider a three stage oligopoly model with n ...rms and an utilitarian regulator. In the rst stage, the regulator chooses a legal environment. Four types of actions are considered: the regulator may choose (i) not to intervene (absence of regulation), (ii) to implement a strict liability rule or (iii) to implement a negligence rule, or (iv) to forbid production. The policy selected by the regulator is publicly known by ...rms and consumers. For rules (ii) and (iii), we assume that the Court is able to perfectly identify the responsible ...rm and to verify the extent of the damage. In the second stage, ...rms simultaneously choose
a costly prevention effort and incur the fixed cost of prevention. In the third 
stage, sellers simultaneously select a quantity (i.e., Cournot competition). For 
each firm, a damage, \( D, D > 0 \), representing the cost for the society, may occur 
during the production process, that is in stage three, affecting a third party: 
potential victims are not part of the producers-consumers relationship (external 
damage). We assume that firms as well as consumers and potential victims are 
risk neutral.

All firms have the same marginal cost of production equal to zero for sim-
plicity. They sell a homogeneous product with inverse demand function \( p(Q) = a - Q \). 
The probability of the external damage event is determined by the firm’s 
choice of effort, \( \theta \in [0,1] \). Thus, \((1-\theta)\) denotes the probability that an 
environmental accident occurs. No damage occurs for a maximal level of effort equal 
to \( \theta = 1 \). By selecting a level of effort, the firm incurs a fixed (independent 
of quantity) cost equal to \( \theta^2 \). This cost is sunk and increasing and convex in the 
level of effort.

Before considering the oligopoly market, we briefly describe the first-best 
allocation. In this economy, the maximum welfare would be reached with (i) a 
competitive price equal to the marginal cost of production (namely zero) and (ii) 
a unique firm (namely \( n = 1 \)). The presence of this single firm would facilitate 
the maximum economies of scale linked to the fixed cost \( \theta^2 \) and it would limit 
the expected damage for the society equal to \((1-\theta)D\). The socially optimal 
level of effort minimizes the total expected cost for the society, \((1-\theta)D + \theta^2 \), 
which would lead to an optimal effort equal to \( \theta^* = \min\{D,1\} \). If \( 0 < D < 1 \); 
the effort is \( \theta^* = D \) and the probability of getting a damage is \( 1 - D \). If 
\( D = 1 \); the effort is \( \theta^* = 1 \) and no damage will occur. Note that the value of 
\( \theta^* \) remains unchanged whatever the number of competing firms. Implementing 
this socially optimal level of effort together with a (socially optimal) competitive 
price would result in a loss for the seller. This suggests that public intervention 
seeking to implement a first-best equilibrium would require imposing a price 
equal to marginal cost and subsidizing the monopolist through public funding of 
the fixed costs associated with the prevention activity. This also suggests that 
a second-best (and realistic) policy should take into account the environmental 
risk (externality) along with the market structure, namely the number of sellers 
and the resulting solvency problems. As the prevention effort is costly for 
the seller, this extra cost can only be covered through a sufficient market price 
(depending on \( n \)).

We now turn to the characterization of the subgame perfect Nash equilib-
rium of this three stage game and then conduct a welfare analysis allowing the 
selection among the different regulations.

3 Private choice under alternative rules

As the firm’s effort results in a fixed (independent of quantity) cost, it does not 
interfere with the choice of the output level, so that the production stage (stage 
3) can be presented without loss of generality.
3.1 Production stage

Considering that \( n \) firms are active on the market, the per-seller gross profit is \( (a - Q_i)q_i \), with the overall demand given by \( Q = \sum_{i=1}^{n} q_i \). The profit maximization gives the first-order condition \( a - 2q_i - \frac{P}{\sum_{i=1}^{n}} q_i = 0 \). Under a symmetric Cournot-Nash equilibrium, all firms adopt the same strategy. Thus with \( q_i = q \) substituted in this first-order condition, we get the per-firm equilibrium quantity, \( q^* = a(n+1) \) and the overall quantity ordered by the \( n \) firms is \( Q^* = na(n+1) \).

Thus, the per-seller gross profit is

\[
\frac{1}{4}(n) = \frac{a}{n+1} \mu \quad (1)
\]

A firm produces a positive quantity as soon as its profit net of the prevention costs, \( \frac{1}{4}(n) \), is positive for different values of \( a \) \([0, 1]\). For consumers, surplus is

\[
\frac{1}{2} + \frac{1}{2} \mu \quad (2)
\]

3.2 Private Effort Choice

The private effort choice is derived considering the production activity gross profit and the legal environment as given.

3.2.1 Absence of regulation

When no liability regulation is imposed by the regulator, the profit-maximization condition leads firms to make no effort, namely choose \( \bar{\varepsilon} = 0 \), so that the probability of accident is equal to one for each firm. The society bears all the risk and the overall externality is equal to \( nD \).

3.2.2 Strict liability

Under strict liability, a firm incurs some liability payments when the damage occurs. This gives a sufficient incentive for each firm to make a prevention effort since the court is able to verify perfectly each firm's action. The liability payments depend on the magnitude of net profits, namely the gross profit given by (1) minus the sunk cost of prevention, \( \frac{1}{4}(n) \), with respect to the damage \( D \). More precisely, when the damage occurs (event with probability \( (1 - \bar{\varepsilon}) \)), the firm covers it, as long as the profit net of the damage is positive, namely for \( \frac{1}{4}(n) \), the firm has sufficient earnings to totally cover the damage: the limited liability constraint is satisfied. In that case,
we consider that the rm covers the damage up to the level of its net pro.ts, meaning that it incurs a liability payment of \( \frac{3}{4}(n - \frac{1}{2}) \). It is easy to see that the higher \( n \) and \( D \), the lower \( b \). So we get the following de.nition.

**Definition 1** Considering \( n \), \( a \) and \( D \) as given, a rm is either

- always judgment proof with \( b = 0 \) for \( D \cdot H(a) = \frac{a}{n + 1} \cdot 2 
- always solvent with \( b = 1 \) for \( D \cdot L(a) = \frac{a}{n + 1} \cdot \frac{1}{2} 
- or potentially judgment proof with \( 0 < b < 1 \) for \( D > H(a) > L(a) \).

This de.nition states that for low values of \( a \) and high values of \( D \), a rm is always judgment proof. For high values of \( a \) and low values of \( D \), a rm is always solvent. Finally, for “intermediate” values of \( a \) and \( D \), the ex ante choice of exert, made by each rm may influence its solvency situation. In other words, rms may make a strategic use of insolvency for \( D > b \cdot D \); this case is depicted in Figures 1 and 2 by the area between the dotted lines \( L(a) \) and \( H(a) \). For these particular values of \( a \) and \( D \), a rm may have to choose among several prevention levels which influences its solvency situation.

The ex ante choice of exert, , determines the ex post liability payments under strict liability:

\[
L = \begin{cases} 
D & \text{if } b = 1 \text{ (solvent rm)} \\
\frac{3}{4}(n - D - \frac{1}{2}) & \text{if } b > 1 \text{ (judgement proof rm)}
\end{cases}
\]

Observe that this liability payment depends on the exert level and on the market structure only when the solvency constraint is effective, namely for \( b > D \). In that case, the liability payment is a decreasing function in the exerted cost of prevention and in the number of rms that are active on the market. Otherwise, the liability payment only depends on the monetary cost of the accident to victims.

We now detail the per-rm pro.t according to the different events. With a probability \( \frac{3}{4} \), no damage linked to the rm production occurs and the per-rm net pro.t is \( \frac{3}{4}(n - \frac{1}{2}) \). With a probability \( \frac{1}{4} \), the damage \( D \) linked to the rm production occurs. The pro.t is \( \frac{3}{4}(n - D - \frac{1}{2}) \) for the solvent rm, and zero for the insolvent rm (since its net pro.ts are taken for victims’ compensation). So that under strict liability (5), the net ex ante expected pro.t (expectation taken with respect to the environmental damage) for a rm writes

\[
\frac{1}{2}S(n) = \begin{cases} 
\frac{3}{4}(n - D - \frac{1}{2}) & \text{if } b = 1 \text{ (solvent rm)} \\
\frac{3}{4}(n) & \text{if } b > 1 \text{ (judgement proof rm)}
\end{cases}
\]

where \( \frac{3}{4}(n) \) is given by (1). Each rm selects a level of exert that maximizes \( \frac{1}{2}S(n) \). The optimal level of exert indeed selected by the rm will depend on
the magnitude of pro...t, or more precisely on the maximum willingness to pay of consumers, \( a \), with respect to the damage, \( D \). Let

\[
b(n) = (n+1)^{\frac{3}{2}}
\]

\[
D_1(a) = 1 + 2 \frac{a}{n+1} + 2 \frac{a}{n+1} \frac{2}{3}
\]

\[
D_{eq}(a) = \frac{a}{n+1} \frac{2}{3}
\]

where frontiers \( b(n) \) and \( D_1(a) \) allow to delimit the sellers choices. Under strict liability, the optimal private choice of exert is characterized in the following proposition:

**Proposition 1** Consider \( a < b(n) \). A rm chooses a socially optimal level of exert, \( \mathcal{a} = \mathcal{e} = \text{Min}[D; 1] \). Consider now \( a > b(n) \). A rm that is always solvent chooses a socially optimal level of exert, \( \mathcal{a} = \mathcal{e} = D \). A rm that is potentially judgment proof chooses a socially optimal exert \( D \), if \( D > D_1(a) \), and an exert equal to \( \mathcal{a} = \frac{a}{n+1} \frac{2}{3} \); if \( D < D_1(a) \). A rm that is always insolvent chooses an exert equal to \( \mathcal{a} = \frac{a}{n+1} \frac{2}{3} \).

Under potential insolvency, the exert can be higher than the socially optimal exert (if \( D_{eq}(a) > D > D_1(a) \)) or lower (if \( D > D_{eq}(a) \)).

**Proof:** see appendix 1.

Proposition 1 is summarized in Figure 1. The X-axis represents consumers’ maximum willingness to pay, \( a \), for the product, and the Y-axis the value of the damage, \( D \). First, for high values of \( a \) and \( D \) (area I), rms spontaneously make a maximum exert: the perspective of a high gross pro...t allows a greater investment in prevention, and the threat of a high liability payment is a sufficient incentive to completely eliminate the risk\(^1\). Second, when the damage value is not too high with respect to consumers’ maximum willingness to pay (area II), rms choose the socially optimal exert, \( D < 1 \). The damage, if it occurs, will be completely borne by rms that have sufficient earnings. Eventually, when the damage is high but the consumers’ maximum willingness to pay is low (area III), the prevention exert is lower than 1 and the solvency constraint is effective: rms won’t be able to pay for the whole damage when it occurs. Note that under strict liability, for intermediate values of \( (a; D) \)-the hatched part of area III - rms may choose a level of exert that is greater than the socially optimal exert. Potentially judgment proof rms get higher pro...ts by overinvesting in prevention and hence increasing the probability of bankruptcy than by choosing the socially optimal level of exert (equal to \( D \)). The strategic use of insolvency is thus underscored.

\(^1\)This holds with a more sophisticated specification of the cost function (e.g. \( f(\mathcal{a}) \)), which simply results in a shift in the lower limit of area I (e.g. \( D = f \) instead of \( D = 1 \)).
3.2.3 Negligence rule

Under a negligence liability rule (N), the regulator sets up a kind of standard corresponding to a level of due care that affects the pattern of liability payments. This level of due care is voluntary since it is assumed that (i) this reference previously admitted by the Court sets a precedent and/or (ii) no ex ante control is made before the production stage. If the firms respect the level of due care, the liability payment in case of an accident is driven to zero. If the firms do not respect the due care, they will have to incur liability payments similar to the ones made under strict liability. Considering that the due care is set adequately, namely equal to the socially optimal level of effort, 

\[ \text{firm's ex ante expected profit is} \]

\[ \mathbb{E}\{\pi\} = \frac{1}{2} \quad \text{for} \quad d < \frac{1}{4} \]

\[ \mathbb{E}\{\pi\} = \frac{3}{2} \quad \text{for} \quad d > \frac{1}{4} \]

where \( \frac{1}{4} \) is given by (5). Note that the profit \( \frac{1}{4} \) is the highest possible profit since the firm will not incur any liability payment in case of an accident. This enables a firm to increase its level of effort, which would be beneficial for the society. Indeed, a firm has an incentive to respect the standard (namely \( d > \frac{1}{4} \)) if \( \frac{1}{4} > \frac{3}{2} \). Let:

\[ D_2(a) = \frac{n + 1}{a} \quad \text{for} \quad d \leq \frac{3}{2} \]

Under a negligence rule, the firms' optimal choice leads to the following proposition:

Proposition 2 Consider first \( a < b \). A firm chooses a socially optimal level of effort, \( \frac{d}{b} = \frac{a}{b} \). Consider now \( a > b \). A firm that is always solvent chooses a socially optimal level of effort \( \frac{d}{b} = \frac{a}{b} \). A firm that is potentially judgment proof chooses an effort equal to \( \frac{d}{b} = \frac{a}{b} + 1 \) if \( D > D_2(a) \). Idem for a firm that is always insolvent.

Proof: see appendix 1.

Proposition 2 is summarized in Figure 2. In area I (high values of both \( a \) and \( D \)), firms spontaneously make a maximum effort, just like under strict liability. For low values of \( D \) with respect to consumers' maximum willingness to pay (area II), the optimal level of effort is selected and the damage-if it occurs-will be completely borne by firms who have sufficient earnings. Eventually, in area III the solvency constraint is effective, i.e. firms will not be able to pay for the

2 Setting the negligence due care standard at the socially optimal effort level is the most relevant choice since this level corresponds to a balanced trade-off between the probability of insolvency and the probability of environmental accident (see Burrows, 1999, for an analysis of the simultaneous use of regulation and liability, considering a negligence due care that may be equal to, above or below the regulated standard).
whole damage, as the consumers’ willingness to pay is low and the damage is high. In this last case, the negligence rule is not a sufficient tool for reaching the optimal level of prevention.

One interesting consequence in that under the negligence rule, the firm would never overinvest in prevention as under strict liability (the former hatched area in Figure 1 is now part of area II of Figure 2, where the socially optimal level of prevention is selected). The negligence rule allows each firm to dodge its liability payment by respecting the standard. For a lower level of effort, the liability payment would be made up to the available assets.

Under a negligence rule, the socially optimal level of effort is more often implemented. In particular, for the hatched area in Figure 1, the firm has a higher profit respecting the socially optimal level of effort than choosing a higher level of effort resulting in a higher effort cost and hence an higher probability of insolvency without any benefits in terms of liability payments.

To sum up, the main difference between the two liability rules is that under a negligence rule, the judgment proof problem may lead the firm to exert a suboptimal level of effort, whereas the firm may overinvest (or underinvest) in effort under a strict liability rule.

3.3 The market structure

We now consider the impact of the market structure captured by the number of active firms on private decisions of effort. The higher $n$, the higher is the threshold value, $b(n)$ on the X-axis of Figures 1 and 2. Thus, leaving other parameters unchanged, the maximum effort $\bar{\varepsilon} = 1$ (such that the risk completely disappears) is less likely to be adopted. Recall that this level of effort is selected for $a, b(n)$ and $D, 1$ under any liability rule. More generally, an increase in the number of firms, $n$, leads to a decrease of areas I and II towards the East and an increase of area III towards the East and the SouthEast (in Figures 1 and 2). In area III, the increase of $n$ entails a decrease of the prevention effort $\varepsilon = \frac{n^{\frac{2}{2}} - \frac{3}{2}}{3}$.

Proposition 3 The less concentrated the market, the less often the socially optimal level of effort is implemented, and the lower the effort level under insolvency (effective or potential).

This highlights the tradeoff between market structure and risk management.

Proposition 4 The strategic use of insolvency under strict liability is observed whatever the market structure.

The market structure appears as an important parameter for the private firm. First, a monopoly may well choose an inefficient level of effort which contrasts with the common idea that a monopoly will be more efficient with respect to prevention than a duopoly or an oligopoly. In addition, for particular values of $a$ and $D$, a monopoly may choose to overinvest in prevention whereas
for the same values of $a$ and $D$, a duopoly would choose to underinvest in prevention. Also, the fact that a suboptimal level of effort emerges under both strict liability and negligence rules, whatever the market structure contrasts with Spulber (1989, Chapter 14) who opposed the efficiency of liability rules under a competitive situation to the inefficiency of liability rules under a monopoly situation.

The case of a competitive situation, excluded up to now, may be captured by making $n$ go to infinity. When $n \to +\infty$, the optimal private effort choice corresponds to the choice under no regulation, $\bar{\tau} = 0$, and the strategic use of insolvency disappears (as $D_1(a) = 0$, $b(n) = (n + 1)^{3/2} + 1$ and $\bar{\tau} = \frac{a}{n+1}$).

The market structure may as well be an important parameter for the regulator in his choice of a legal environment as we shall see in the following section.

4 Welfare analysis

We now consider the viewpoint of a utilitarian regulator. Comparison of welfare as well as positivity conditions on various welfare give some informations about the action to be chosen by the government given $(a; D)$. Let

$$D_{SOD}(a) = \frac{1}{n+1} \frac{2a^2 + 2n}{1 + n} \frac{1}{2}$$
$$D_{JP}(a) = \frac{2a^2}{n+1} + \frac{1}{2}$$

Proposition 5 Consider $a < b(a)$. Both liability rules are equivalent and preferred to no regulation. Consider now $a > b(n)$. If $D \cdot D_1(a)$, both liability rules are equivalent and preferred to no regulation. Idem if $D_{JP}(a) > D > D_2(a)$.

If $\text{Min} \{D_{SOD}(a); D_2(a)\} > D > D_1(a)$, a negligence rule is preferred to a strict liability rule.

Finally, if $D_{SOD}(a) > D > \text{Max} \{D_2(a); D_{JP}(a)\}$, banning the activity is the preferred action. Idem if $D > D_{SOD}(a)$.

The proposition 3 is illustrated in Figure 3. The two liability rules are equivalent and preferred to no regulation, for (i) high values of $a$, the damage $D$ (with an effort equal to one), (ii) relatively low values of $D$ compared to $a$ such that $D < D_1(a)$ (with an effort equal to $D$), and (iii) relatively high values of $D$ compared to $a$ such that $D < D_{JP}(a)$ and $a < b(n)$ (with an effort equal to $\bar{\tau} = \frac{a}{n+1}$). For high values of $D$ and small $a$ (hatched area), banning the activity could be welfare maximizing as
the solvency problem is really acute. In this case the surplus resulting from the exchange does not offset the expected damages. For values of \( a \) and \( D \) such that \( D_1(a) < D < D_2(a) \), a negligence rule is preferred to a strict liability rule, the former allowing to implement the socially optimal effort. The negligence rule allows the reduction of the inefficiency associated with a strict liability rule which results in a overinvestment in prevention by the firms.\(^3\)

The market structure is important in the choice of a legal environment. For some particular values of \( a \) and \( D \), the regulator may choose to ban the activity for a duopoly or even an oligopoly whereas for the same values of \( a \) and \( D \), a monopoly may be allowed to produce but subjected for example to a negligence rule. These results suggest that a complete industrial organization analysis must be conducted for selecting the appropriate regulation.

## 5 One extension: The internality case

One interesting extension is to investigate the strategic use of insolvency when the damage is at least partially internalized by consumers, as it is the case for products safety.

All assumptions of section 2 are kept. We only modify the assumption linked to the overall damage \((1 - \gamma) nD\). Let \( 0 < 2 \in [0; 1] \) denote the share of the damage incurred by the third party and \((1 - \gamma) \) the share incurred by the consumers. The third party incurs \((1 - \gamma) nD\) and the consumers incur \((1 - \gamma)(1 - \gamma) nD\); where consumers have rational expectation concerning this expected damage and perfect information concerning \( \gamma \). The value \( \gamma = 0 \) refers to a pure internality case, while \( \gamma = 1 \) refers to a pure externality case (studied previously). The consumers' expected indirect utility is now \( u = aQ - Q^2 = aQ - pQ \gamma \) \((1 - \gamma) nD\), where \( Q \) denotes the overall demand (equal to the production). Thus, \( \partial u/\partial Q = a - 2Q = 0 \), leads to the same inverse demand \( p = a/Q \) as before. This leads to the same equilibrium quantity \( Q^e \) and price \( p^e \) given in section 3.1. However, the consumer now decides to buy some products when the surplus coming from the exchange is higher than the damage that they incur, namely for \( u > 0 \). Using \( cs(n) \) given by (2), the consumers decide to purchase goods when \( cs(n) > (1 - \gamma)(1 - \gamma) nD \). Firms expect this consumers' behavior.

Compared to the previous study under externality, the same methodology could be applied to the internality case with \( \gamma = 0 \).

Under the absence of rule, firms strategies differ from the externality case (presented in subsection 3.2.1). Each firm maximizes the gross profit given by (1) minus the sunk cost of prevention, namely the net profit \( 3\gamma (n) j^2 = 2 \), subject to the constraint that consumers purchase; \( cs(n) > (1 - \gamma) nD \). This

\(^3\)This welfare analysis could be completed by taking into account the costs of the different regulations, including the cost linked to the Court. For instance, the complete prohibition of the production (with all the associated controls) could be more costly than the liability rules.
last constraint is satisfied for $\gamma$ with

$$\gamma = \max \left[ 0, \frac{1}{2} \left( \frac{a}{n+1} \right)^2 \right]$$

(13)

The firms choose the level $\gamma = \gamma', \gamma as soon as $\gamma(n) = \gamma^2 > 0$ that is for $D = D_P(a)$ where $D_P(a) = \frac{n}{2} \left( \frac{a}{n+1} \right)^2 \frac{n+1}{n+1, a^2}$. Otherwise, firms choose not to invest in prevention $(\gamma = 0)$ either because firms get negative profits (this is the case for $D > D_P(a)$) or because the maximum willingness to pay for consumers is so high with respect to the level of damage that incurring the risk is not an issue (this happens for $D < \frac{n}{2} \left( \frac{a}{n+1} \right)^2$). In absence of regulation, incentives to invest in prevention are diluted: firms choose an effort level that differs from the socially optimal one. Moreover, for values of $a$ and $D$, such that the social optimum effort is 1, as $\gamma < 1$, firms underinvest in prevention. For values of $a$ and $D$ such that the social optimum effort is $D$, it could be that firms overinvest in prevention.

How does regulation could reduce these inefficiencies? Under a strict liability rule, in case of an accident, consumers are fully indemnified as long as $\frac{\gamma(n)}{2} > 0$ that is for $\gamma > b$, where $b = \frac{2\gamma(n)}{D^2}$. A firm solves the following optimization problem

$$\max \left[ \frac{\gamma(n)}{2} \right] \text{s.t.: } cs(n) \leq 0$$

In case of a judgment proof firm, consumers are partially compensated and they buy the product as long as $cs(n) \leq 0$ that is for $\gamma > b$, where $b = \frac{2\gamma(n)}{D^2}$. A potential judgment proof firm will choose an effort level solution to

$$\max \left[ \frac{\gamma(n)}{2} \right] \text{s.t.: } cs(n) \leq 0$$

Under liability regulation, results are similar to the externality case: some inefficiencies are reduced. Except for high values of $D$ with respect to $a$ for which consumers prefer not to purchase the good: for these parameters values, one has market closure due to the absence of demand.

6 Concluding remarks and other possible extensions

Using a very simple model of oligopoly under alternative rules, we have shown that the judgement problem can result in an over- or underinvestment in prevention, and that the negligence rule does not necessary solve the judgment...
proof problem. Our paper underlines that an efficient policy for managing external risks entails a precise analysis of the complete environment which amounts to a cost-benefit analysis. This is particularly true for the cases where the judgment proof appears as a strategic variable for the firms. We showed that both liability rules are limited for impeding the risk of damages, when the extent of damage becomes relatively large compared to the buyers’ maximum willingness to pay. The result suggests that alternative instruments such as banning the production and/or limiting the number of firms have to be used.

New instruments in the field of public regulation of environmental risks could also be interesting with respect to the strategic use of insolvency. For example, recent theoretical papers have considered the possible extension of liability to banks or insurance companies (cf. Pitchford, 1995, and Boyer and Laxont, 1997). The requirement that potential polluting industries set monetary guarantees aside (bonds) before the beginning of the industrial activity may be an alternative solution to potential insolvency. More generally, financial responsibility may mitigate the insolvency problem (cf. Fees and Hege, 1999b). Such measures of course modify firms’ incentives with respect to prevention.
APPENDIX 1: Private Strategies

Proof of proposition 1: At interior solutions, first order conditions of profit maximization with respect to the prevention effort level are:

\[ D \hat{=} = 0 \text{ if } \hat{=} \leq \hat{b} \]
\[ \frac{\partial \pi}{\partial \hat{}} = 2 \hat{t} \hat{=} = 0 \text{ if } \hat{ > } \hat{b} \]

where the expression of \( \frac{\partial \pi}{\partial \hat{}} \) is given in (1). One gets the following value functions:

\[ \hat{p} = \frac{3}{n+3} \hat{D} + D^2 = 2 \text{ if } \hat{ < } \hat{b} \]
\[ \hat{p} = \frac{2}{n+3} \hat{a}^3 \hat{b}^2 = 2 \text{ if } \hat{ > } \hat{b} \]

Consider first \( a, b(n) \) (where the threshold \( b(n) \) is determined by the relation \( \hat{e} = \frac{a}{n+1} \hat{D} = 1 \)). The optimal choice is the socially optimal effort level \( \hat{e} = \min\{D; 1\} \) whether one has \( D < 1 \) or \( D > 1 \).

Consider now \( a < b(n) \). A rm that is solvent for sure chooses the socially optimal effort, \( \hat{e} = D \). A potentially judgment proof rm may choose between \( \hat{e} = \hat{D} \) and \( \hat{e} = \frac{a}{n+1} \hat{D} \). It chooses the socially optimal level of effort if \( \hat{p} = \frac{3}{n+3} \hat{D} \), that is if \( D \cdot D_1(a) \). The optimal effort \( \hat{e} = \frac{a}{n+1} \hat{D} \) is selected when \( D > D_1(a) \). This level of effort is greater than the socially optimal level \( \hat{e} = D \) when \( D \cdot D_\infty(a) \) and lower otherwise.

Proof of proposition 2: Consider first \( a, b(n) \). The optimal choice is the socially optimal effort level \( \hat{e} = \min\{D; 1\} \) whether one has \( D < 1 \) or \( D > 1 \).

Now consider values of \((a; D)\) such that \( a < b(n) \) and \( D < 1 \). A rm that is always solvent chooses \( \hat{e} = D \). A rm either insolvent for sure or potentially insolvent may choose between \( \hat{e} = \frac{a}{n+1} \hat{D} \) and \( \hat{e} = D \). When \((a; D)\) are such that \( D \cdot D_\infty(a) \), the optimal private effort is \( D \) with this level of prevention effort, the rm escapes its liability and incurs a minimal effort cost. When \( D > D_\infty(a) \), a rm that is insolvent for sure or potentially insolvent has incentives to meet the standard if the ppnt net of liability payments is greater while choosing \( D \) rather than \( \hat{e} = \frac{a}{n+1} \hat{D} \), namely

\[ \frac{\mu \hat{a}}{n+1} D^2 \hat{=} \frac{2 \mu \hat{a}}{n+1} \hat{D} \hat{=} 2 \hat{b} \]

that is \( D \cdot D_2(a) \). Hence, for \( D_2(a) \), \( D > D_\infty(a) \), \( \hat{e} = D \). And for \( D > D_2(a) \), \( \hat{e} = \frac{a}{n+1} D_2 < D \).

For values of \((a; D)\) such that \( a < b(n) \) and \( D = 1 \), that is the standard corresponds to the maximum level of effort, \( D = 1 \); one has \( \hat{e} = \frac{a}{n+1} D_2 \).
D = 1, and a rm that is either always judgment proof or potentially insolvent has no incentives to respect the standard. Indeed, for such a rm to choose the standard, one must have

\[ \frac{\mu a^{\frac{1}{n+1}}}{2} \leq \frac{1}{2} \cdot \frac{\mu a^{\frac{1}{n+1}}}{3} \]

an inequality that is never satisfied whatever \( a \). Hence, \( \frac{a^{\frac{1}{n+1}}}{2} = \frac{1}{2\cdot 3} \).

Finally, for values of \((a; D)\) such that \( a < a(n) \) and \( D > 1 \), only \( \frac{a^{\frac{1}{n+1}}}{2\cdot 3} \) can be implemented.

**Proof of proposition 3:** Direct considering the derivative of \( \frac{a^{\frac{1}{n+1}}}{2\cdot 3} \) with respect to \( n \).

**Proof of proposition 4:** Direct since the relevant expressions characterizing the strategic use of bankruptcy under strict liability, \( D_{eq}(a) \) and \( D_{1}(a) \) depend on \( n \).

**APPENDIX 2: Welfare Analysis**

By taking into account the fact that the prohibition of the production leads to a welfare equal to zero, the following table gives the optimal welfare for the different levels of effort selected by the rns.

<table>
<thead>
<tr>
<th>Prevention Effort</th>
<th>Welfare</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \mu = 0 )</td>
<td>( W_0(n) = n \cdot \frac{a^{\frac{1}{n+1}}}{3} \cdot \left[ 1 + \frac{n}{2} \right] i \cdot nD )</td>
</tr>
<tr>
<td>( \mu = D )</td>
<td>( W_{SOD} = n \cdot \frac{a^{\frac{1}{n+1}}}{3} \cdot \left[ 1 + \frac{n}{2} \right] i \cdot nD \cdot \left[ 1 - \frac{n}{2} \right] )</td>
</tr>
<tr>
<td>( \mu = \frac{a^{\frac{1}{n+1}}}{2\cdot 3} )</td>
<td>( W_{JP} = n \cdot \frac{a^{\frac{1}{n+1}}}{3} \cdot \left[ \frac{3}{2} + \frac{n}{2} \right] i \cdot nD \cdot \left[ 1 - \frac{a^{\frac{1}{n+1}}}{2\cdot 3} \right] )</td>
</tr>
<tr>
<td>( \mu = 1 )</td>
<td>( W_{SO1} = n \cdot \frac{a^{\frac{1}{n+1}}}{3} \cdot \left[ 1 + \frac{n}{2} \right] i \cdot \frac{n}{2D} )</td>
</tr>
</tbody>
</table>

**Proof of proposition 5:** Consider rst a \( a \) \( b(n) \), both liability rules prescribe the socially optimal level of effort, either D or 1. As \( W_{SOD} > W_0 > 0 \) and \( W_{SO1} > W_0 > 0 \), both rules are equivalent and preferred to no regulation.

Let now consider \( a < b(n) \).

If \( D < D_1(a) \), both liability rules prescribe D and one as \( W_{SOD} > W_0 > 0 \) so that both liability rules are equivalent and preferred to no regulation. Idem if \( D_1(a) > D > D_2(a) \); both liability rules prescribe \( \mu = \frac{a^{\frac{1}{n+1}}}{2\cdot 3} \) and one has \( W_{JP} > W_0 \).

If \( \min[D_{SOD}(a); D_2(a)] > D > D_1(a) \), a negligence rule prescribes D whereas a strict liability rule prescribes \( \mu = \frac{a^{\frac{1}{n+1}}}{2\cdot 3} \). As \( W_{SOD} > W_{JP} \),
a negligence rule is preferred to a strict liability rule. And as $W_{SD} > W_0$, a negligence rule is also preferred to no regulation.

If $D_{SD}(a) > D > \max[D_2(a); D_{JP}(a)]$, both rules prescribe $\mu = \frac{a}{n+1} \frac{p}{2a}$ leads to a negative welfare. So that to forbid the activity is the optimal action for the regulator. Idem if $D < D_{SD}(a)$:

for $D_2(a) > D \leq D_{SD}(a)$, $D$ is prescribed under a negligence rule, $\mu = \frac{a}{n+1} \frac{p}{2a}$ under a strict liability rule and $W_{JP} < W_{SOD} < 0$. And for $D < \max[D_2(a); D_{SD}(a)]$, both liability prescribe $\mu = \frac{a}{n+1} \frac{p}{2a}$ and $W_{JP} < 0$.¥
Figure 1: Private choice of effort under strict liability
Figure 2: Private choice of effort under a negligence rule
Figure 3: Optimal action for the regulator
References


