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ENVIRONMENTAL RISKS : SHOULD BANKS BE LIABLE?

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RÉSUMÉ

On étudie ici l'effet de la responsabilité des banques pour les dommages environnementaux causés par leurs clients. Les tribunaux qui rendent les banques responsables de la réparation des dommages poursuivent le double objectif de trouver un payeur et de faire pression sur les partenaires des firmes qui peuvent inciter ces dernières à la réduction des risques. On étudie l'impact que de tels jugements peuvent avoir sur les relations de financement et sur les incitations à la prévention dans un environnement où les banques ne peuvent s'engager à toujours refinancer la firme. À la suite d'un accident environnemental, les banques légalement responsables sont plus enclines à refinancer la firme en cause. On montre alors que la responsabilité bancaire facilite le refinancement, améliorant ainsi le partage de risque obtenu par la firme. Mais, par là-même, elle diminue les incitations des firmes à la prévention. On montre également que lorsqu'il y a responsabilité bancaire, le montant investi en technologie de prévention correspond à l'optimum privé. Si le niveau d'investissement socialement efficace est supérieur au niveau optimal privé, l'absence de responsabilité bancaire, qui pousse les firmes à surinvestir en capacité de prévention, peut être socialement désirable.

Mots clés : environnement, responsabilité bancaire, contrats financiers, non-engagement

ABSTRACT

This paper studies the impact of banks' liability for environmental damages caused by their borrowers. Laws or court decisions that declare banks liable for environmental damages have two objectives : (1) finding someone to pay for the damages and (2) exerting a pressure on a firm's stakeholders to incite them to invest in environmental risk prevention. We study the effect that such legal decisions can have on financing relationships and especially on the incentives to reduce environmental risk in an environment where banks cannot commit to refinance the firm in all circumstances. Following an environmental accident, liable banks more readily agree to refinance the firm. We then show that bank liability effectively makes refinancing more attractive to banks, therefore improving the firm's risk-sharing possibilities. Consequently, the firm's incentives to invest in environmental risk reduction are weakened compared to the (bank) no-liability case. We also show that, when banks are liable, the firm invests at the full-commitment optimal level of risk reduction investment. If there are some externalities such that some damages cannot be accounted for, the socially efficient level of investment is greater than the privately optimal one. In that case, making banks non-liable can be socially desirable.

Key words : environment, bank liability, financial contracts, non-commitment

1 Introduction

In the last ten years, many court settlements in the United States have been imposing a transfer of liability for environmental damages to banks.[1] These court decisions were made possible by the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA). This law allows judges to turn against any party that could be considered as an "owner" or an "operator" of the firm responsible for the polluting accident. Banks that have close relationships with their debtor firms and that can have a say in their administrative decisions can therefore be considered as "operators". The legislator's objective in designing CERCLA was primarily to allow courts to find a party who could pay for environmental damages when liable firms go bankrupt.[2] This avoids resorting to public funds to compensate victims and repair damages after environmental accidents caused by insolvent firms' negligence. In fact, the legislator wishes to declare liable, the deep-pocket stakeholders who benefited from firms' dangerous activities. Vertically related firms and financial partners can then be considered as "operators" and held liable for damages.

The obligation, however, to turn against firms' partners underlines the fact that firms are not fully insured against environmental risks. If firms can assume small environmental accidents without going bankrupt, it is more difficult to deal with large accidents that can have catastrophic consequences that could lead to the liable firm's bankruptcy. Such accidents classified as "major technological risks" have low probabilities of realization but highly prejudicial consequences. For example, industrial accidents involving nuclear, oil, or chemical spills are major technological risks. For that reason, even insurance companies may not be able to assume those risks because they cannot easily compute fair premia for those low frequency accidents. Furthermore, they cannot commit to pay indemnities for eventually very large damages that could easily overweight their reserves. Finally, firms protected by limited liability have low incentives to buy insurance for the value of damages when these are greater than their asset value. Consequently, firms are often not or incompletely insured against major environmental risks and liabilities have to be determined ex post and settled by court judgments.

A second objective for making banks liable for their clients' negligence is to incite them into giving their clients strong incentives for taking greater care for the environment. If

[1]For more details on these settlements, see Goble (1992) or Boyer and Laffont (1995) for Canadian cases.
[2]For more details on the CERCLA, see Olexa (1991) or Henderson (1994).

banks have a seat on firms' administrative boards, it can be useful to give them concern about environmental care. The legislator then expects banks to monitor firms' activities and especially their environmental risk prevention policy. The reason why firms have not themselves the right incentives for environmental risk reduction is that their liability for environmental accidents is limited by the bankruptcy possibility. In the case of bankruptcy, victims' compensation has priority over creditors' claims. But the amount of damages that can be claimed from firms by courts cannot be higher than their asset value. The incentives they have to take preventive measures are limited to this value. In the case of major risks, it is usually lower than the social cost of damages. Firms then only take into account the reduction of a loss risk of the asset value and not of the entire value of social damages. They are, therefore, not internalizing completely the consequences of environmental accidents. Imposition of environmental liability to banks can be seen as a way to relax the firm's limited liability constraint by allowing the internalization of damages by the bank/firm duo. For this to be efficient, financial contracts between banks and firms have to give appropriate incentives to those who take environmental decisions.

Imposition of proper incentives through financial contracts depends on the informational environment contracts are signed in. Suppose, first, that the risk reduction investment is observable and verifiable by banks. This implies that covenants in financial contracts can impose a specific level of investment. Beard (1990) shows that, when no bank is involved, limited liability can have two opposite effects on firms' incentives to invest in risk reduction technologies.[3] On one hand, as the expected payment, due to limited liability, is less than the real expected damage, the marginal benefit of prevention is too small and the firm underinvests. But, on the other hand, because less resources are invested in productive activity, more risk reduction investment decreases the amount the firm loses in case of bankruptcy. This effectively entails overinvestment. This second effect is very dependent on the form of the ex post damages distribution and the dominant effect is generally the underinvestment one. In this case, the introduction of financial contracts has to provide incentives in order to avoid the limited liability effect. Segerson and Tietenberg (1992) show that, in a complete information-no bankruptcy environment, liability could be imposed as well on the bank as on the firm to generate optimal incentives.[4] This means that transfers between the parties can offset adverse liability effects in order to preserve incentives as well as participation interest.

[3] In this model, the amount of damages as well as the accident's realization are random.

[4] In fact they consider a principal-agent contract between a firm and its manager but it is easy to transpose it to the case of a bank/firm relationship.

When the risk reduction investment cannot be observed by the bank, however, financial contracts can no longer include covenants that would specify a level of investment. In that case, liability has to be given to the firm. If not, the contract is not able to preserve incentives. This result highlights two important points. First, moral hazard on prevention efforts will annihilate the incentive effects of bank liability. Second, the principle of firms' limited liability prevents the legislator from providing incentives by giving liability to firms. Moral hazard and limited liability are the two reasons given in the literature to explain why bank liability is not the perfect mechanism for providing risk reduction incentives. Boyer and Laffont (1997) show that, in a moral hazard environment, partial bank liability is preferable to complete liability. They use a two-period model with preventive effort to be made by the firm in the first period, a possible accident taking place in the second, and financing required in both periods. If effort is fully observable, complete bank liability entails the socially optimal prevention effort and financing behavior at the Nash equilibrium of the contract. But if effort is not observable, the monopoly bank has to abandon rents to the firm. The usual trade-off between rent extraction and incentives leads to sub-optimal levels of financing and effort. The authors then show that the equilibrium allocation could be closer to first best, if bank liability could be restricted to a fraction of the damages. Pitchford (1995) also finds that partial bank liability is the best solution. In a one period-moral hazard model, bank liability induces financial contracts to impose risk premia to firms in the no-accident states. This reduces the firms' incentives to reach those states, hence it reduces their effort. Pitchford concludes that the efficient level of bank liability is equal to the firm's asset value. This is equivalent to recommending a no bank liability solution.

In this paper, we introduce several features which have, to some extent, been ignored in the literature and which are likely to affect how bank liability interacts with risk reduction investment. Bank liability following an environmental accident determines the bank's incentives to refinance the firm. The expectation of such refinancing should affect the ex ante investment the firm makes to reduce environmental risk. So, we first introduce in our model dynamics to explicitly take into account the bank's refinancing decision. Second, we assume that the firm is risk averse so that it is averse to environmental risk and it values refinancing following an environmental accident.[5] Assuming that the firm is risk averse produces the intuitive result that the threat of bankruptcy induces the firm in overinvesting to avoid it.

[5]It can be argued that when managers as well as workers are risk averse, they influence the management decisions either directly (for the manager) or indirectly through labor contract negotiations. Consequently, firms behave as if they were risk-averse.

This is not always the case in models with risk neutrality; in these models, limited liability and bankruptcy usually induce the firm in underinvesting instead of overinvesting to avoid the risk, and this, because the firm is not responsible for losses in bankrupt states.

With the introduction of dynamics and risk aversion, we can show that bank liability is not necessarily a good way to provide incentives for risk reduction efforts. Our conclusion, however, does not rest on the firm's limited liability constraint, nor on the asymmetric information environment. It results from the parties' inability to commit to long-term financial contracts. Risk averse firms have incentives to smooth their income through time as well as through states of nature. Because of the incompleteness of markets, firms cannot perfectly insure through the use of financial securities. But they can enter into long-term relationships with financial intermediaries in order to achieve some smoothing of their payoffs. These long-term relationships emerge through contractual agreements that finance firms' projects as well as share their risks. Furthermore, it is highly relevant to study the problem of bank liability with long-term contracts because they imply a close relationship between the bank and the firm and therefore justify the fact that a court can ex post consider the bank as a firm "operator".

Formally, we assume that the bank cannot commit to maintain the relationship if it is not in its interest to do so. This implies that the bank accepts to refinance the firm in states of nature where its income is low only if this refinancing is marginally profitable. Contracts that satisfy this constraint are called "self-enforcing contracts". Self-enforcing financial arrangements cannot usually implement the first-best allocation. Under such contracts, the extent of risk-sharing and smoothing depends on the bank's autarcic opportunities. We show that bank liability transforms its autarcic payoff. Bank liability effectively relaxes its self-enforcing constraints, thus providing better risk-sharing to the firm. This implies that the firm gets reduced incentives for environmental risk reduction investment. The intuition is that, under imperfect financial contracts, financial transfers and the risk reduction investment become imperfect substitute. As the bank can provide better insurance, the firm reduces its investment.

We solve our model for two distinct cases. First, we assume that the value of the firm remains positive following an environmental accident. Second, we study the opposite case where the value of the firm becomes negative following the accident. Bank liability cases observed in real life are cases following the bankruptcy of liable firms. Unable to recover damage costs from the bankrupt firm, judges have put the burden on deep-pocket partners, as soon as they can be partially responsible for the accident. In fact, when the firm can pay for damages or when its liquidation value is sufficient to cover the damages, creditors are not called for (but in fact they always lose their priority as victims of environmental accidents are payed before creditors following the firm's bankruptcy). Then, the apparent role of laws as CERCLA appears only in the case of bankruptcy. But in fact, because of the possibility of bank ex post liability, sealed in the law, the ex ante form of contracts has to take bank liability into account. This is why there is no need for an actual bankruptcy for bank liability to have an effect on financial contracts. This is why we study the two cases.

In the following section, we present the model. Section 3 characterizes the optimal contract when the environmental accident cannot cause the firm's bankruptcy. It first describes the privately optimal solution, that is, the risk-sharing and level of prevention obtained in the contract when there are no self-enforcing constraints. It then presents the self-enforcing contract's solution as a function of the level of bank liability. Section 4 discusses the same contract when the environmental accident can cause the firm's bankruptcy. In a last section, we discuss bank liability by comparing the risk reduction investment achieved in a self-enforcing contract with bank liability and the socially optimal one. All proofs are relegated to the Appendix.

2 The model

There are three periods over which a bank and a firm interact. In period $t = 1$, the firm faces two sources of risks. First, the net income y^s that the firm receives is stochastic. There are S possible states of income indexed by $s \in \mathcal{S} = \{1, 2, \cdots, S\}$. Denote by q^s the probability of state s and assume that $0 < y^1 < y^2 < \cdots < y^S$. We note $\bar{y} = \sum_{s=1}^{S} q^s y^s = \mathrm{E}_s y^s$ the expected value of income. The second risk is an environmental risk. In the case of an environmental accident, the firm is potentially liable for an amount X for reparation of the damages (decontamination, compensation of the possible victims, ...). The probability of the environmental accident is $p(I)$ where $I \in R^+$ is an observable investment in prevention technology made by the firm in period $t = 0$. The probability $p(I)$ is decreasing and convex: $p' < 0$ and $p'' > 0$. We suppose that the absence of investment cannot make the accident systematic, that is, $p(0) < 1$. On the other hand, the risk cannot be completely eliminated, that is, $p(I) > 0$ for all I. The investment cost is $K(I)$ and we assume that K is strictly increasing and convex: $K' > 0$ and $K'' > 0$, with $K(0) = 0$. We suppose that damages

X are large relative to income but have a relatively low probability of realization, that is, $X > y^s$ and $p(0)X < y^s$ for all $s \in \mathcal{S}$. A state of nature in period $t = 1$ is then represented by a pair (s, x) with $s \in \mathcal{S}$ and $x \in \{0, X\}$. There are $2S$ possible realizations. Note that under our assumptions, $y^1 - X < \cdots < y^S - X < y^1 < \cdots < y^S$.

In period $t = 2$, the firm faces only an income risk where y^z, $z \in \mathcal{S}$, denotes its income. In this period, its income is identically and independently distributed as that in the first period.[6]

The firm is risk-averse and its preferences over dividends[7] are represented by a separable utility function u, strictly increasing and strictly concave: $u' > 0$ and $u'' < 0$. The bank is risk neutral and its utility is equal to its income. The two parties discount the future by a factor β.

There are gains to trade between the firm and the bank because the risk averse firm has an interest in sharing its risk and smoothing its dividends with the bank. To achieve this, the bank and the firm sign a financial contract in period $t = 0$ which specifies the investment level and the firm's contingent dividends. Denote by c_1^{sx} the firm's dividend in period $t = 1$ in state (s, x) and by $c_2^z(s, x)$, its second period dividend level when income y^z is realized in period 2 and state (s, x) occurred in the first period. In periods $t = 1$ and $t = 2$, the expected income $\bar{y}$ is split between the bank and the firm. If c is the dividend level allowed to the firm by the contract in one period, then the bank is given the difference between c and the realized level y of income if there is no environmental accident. In the case of an accident, the bank gets the difference between c and $y - X$. We assume that the bank operates in a competitive environment. Initially, it therefore accepts every contract that yields a non-negative expected surplus. Finally, we must assume that the firm's net actual value NAV is positive for all investment levels of interest, that is,

$$NAV = \beta(1 + \beta)\bar{y} - K(I) - \beta p(I)X > 0.$$

This condition ensures that the firm can secure some initial financing for its investment I.

Informally, a contract specifies the amount which is initially financed by the bank in period $t = 0$, and the schedule of reimbursement over the next two periods, $t = 1$ and $t = 2$.

[6] The period $t = 2$ is introduced to make non trivial the decision to bankrupt or not the firm following an environmental accident in the first period.

[7] Here, the dividend is equal to the net income y^s plus financial transfers.

At the end of period $t = 1$, the firm realizes its income $y^s - x$. For smoothing purposes, it may refinance with the bank with a scheduled reimbursement in period $t = 2$.

In a world of perfect financial markets, liability rules only serve to internalize environmental damages, and the identity of the liable party is not important per se. We therefore assume that markets are imperfect in the sense that the bank cannot commit to the contract if it is not in its interest to do so. As a consequence, if the bank's expected surplus from the contract at the beginning of period $t = 1$, when the state of nature has been realized, is lower than what it can get outside of the contract (in autarky), it breaks its relationship with the firm. Consequently, the optimal contract has to specify transfers that give the bank the incentives to stay in the contract. Formally, *self-enforcing constraints* are introduced in the design of the optimal contract. These constraints guarantee that, in each possible state of nature, the transfer is such that the bank prefers to make it than to breach the contract and return to autarky. These constraints have the following general form:

$$y^s - x - c_1^{sx} + \beta[\bar{y} - \mathrm{E}_z c_2^z(s, x)] \geq aut(s, x).$$

The term $y^s - x - c_1^{sx}$ represents the bank's current net transfer while $\beta\bar{y} - \beta\mathrm{E}_z c_2^z(s, x)$ represents its discounted expected reimbursement. The left-hand side of the constraint therefore represents what the bank gets by staying in the contract following state (s, x). For the bank to stay in the contract, this has to be greater than what it can get in autarky in the same state, denoted by $aut(s, x)$. There are as many self-enforcing constraints as states of nature in period $t = 1$, that is, $2S$. Note that these constraints are more likely to be binding when the current net transfer is negative, that is, when the bank provides additional financing to the firm.

The liability rule affects what the bank can get in autarky. In the absence of bank liability, $aut(s, x) = 0$, where 0 is the assumed reservation utility for the bank. When the bank is liable, the legislator can oblige it to pay an amount k as compensation or penalty after an accident due to the project it finances. Then, even if the bank decides not to refinance the firm after the accident, and hence to "breach" the contract, a court can still force it to remain liable since it was an "operator" of the firm at the time of the accident. This obligation transforms the autarky condition to $aut(s, x) = -k$. Bank liability therefore relaxes the bank's self-enforcing constraint.

The solution for the optimal financial contract not only depends on the liability rules but also on the ex post value of the firm following an accident. Depending on the size of

X, the accident can entail ex post bankruptcy or not. When the accident is not sufficiently harmful, that is, when $y^s - X + \beta\bar{y} \geq 0$, bankruptcy is not optimal regardless of liability rules since it is always efficient to keep the firm operating. We show below, however, that the liability rules announced by the legislator in period $t = 0$ affects the optimal financial contract, even when bankruptcy is not optimal (the no-bankruptcy case).

If $y^s - X + \beta\bar{y} < 0$, then, in a state where an accident occurs, the value of the firm becomes negative. In the absence of rules making either the bank or the firm liable for the environmental damages X, the firm goes bankrupt to avoid paying for the damages and society supports the environmental costs. Bankruptcy is then privately optimal. The introduction of bank liability reverses the decision as damages have to be paid for regardless of whether the firm goes bankrupt or not. In this case, bankruptcy is not privately optimal since $y^s + \beta\bar{y} > 0$.

The object of the paper is to compare the levels of investment in environmental prevention under alternative liability rules and bankruptcy assumptions. Before proceeding to the analysis, we make another assumption. We suppose that, in period $t = 2$, both parties are fully committed to the terms of the contract. This assumption allows us to keep the model tractable and focus on the role of non-commitment (in the first period) on the investment in environmental prevention.[8]

We present our results in two steps. First, we study the no-bankruptcy case in the next section. We then discuss the case where bankruptcy would be privately optimal in the absence of liability rules (the bankruptcy case) in Section 4.

3 The no-bankruptcy case

In this section, we study liability rules under the assumption that the accident is not harmful enough to involve a negative firm value, that is, that bankruptcy is privately non-optimal. Formally, $y^s - X + \beta\bar{y} > 0$ for all s. For the purpose of later comparisons, it is useful to first determine the optimal contract when the bank can commit to it.

[8]This formulation is meant as a reduced form for an infinite-horizon model in which future surplus are used to keep parties bound to the contract. See for example Thomas and Worrall (1988).

3.1 The full-commitment contract

In this sub-section, we present the "first-best" case where the bank can commit to the contract. In period $t = 0$, the amount $K(I)$ is lent by the bank to the firm and invested in the technology. With full commitment, the optimal contract maximizes the firm's expected utility subject to the bank's participation constraint. The bank's participation constraint guarantees that its expected surplus from the relationship is non-negative. The problem can be written as:

$$\begin{aligned}
&\max_{c_1^{sx}, c_2^z(s,x)} (1-p(I))\beta \left(\sum_s q^s (u(c_1^{s0}) + \beta \sum_z q^z u(c_2^z(s,0))) \right) + \\
&\qquad p(I)\beta \left(\sum_s q^s (u(c_1^{sX}) + \beta \sum_z q^z u(c_2^z(s,X))) \right) \\
\text{s.t.} \quad & -K(I) + (1-p(I))\beta \sum_s q^s [y^s - c_1^{s0} + \beta \sum_z q^z (y^z - c_2^z(s,0))] + \\
& p(I)\beta \sum_s q^s [y^s - X - c_1^{sX} + \beta \sum_z q^z [y^z - c_2^z(s,X))] \ \geq \ 0. \qquad (1)
\end{aligned}$$

Denote by λ, the Lagrange multiplier associated with the bank's participation constraint. Characteristics of the optimal dividend are given by the first-order conditions:

$$\lambda = u'(c_1^{sx}) = u'(c_2^z(s,x)) \quad \forall s, z \in \mathcal{S}, \ \forall x \in \{0, X\}.$$

Hence, the firm's dividend is perfectly smoothed by the contract. Denote by $c^* = c_1^{sx} = c_2^z(s,x)$ for all $s, z \in \mathcal{S}$ and all $x \in \{0, X\}$, the constant dividend level offered by the first-best contract. Using this result, the first-order condition for investment can be written as:

$$-\lambda K'(I) + \lambda\beta p'(I)[(1+\beta)\bar{y} - X - (1+\beta)c^* - ((1+\beta)\bar{y} - (1+\beta)c^*)] = 0$$

$$\Leftrightarrow K'(I) + \beta p'(I)X = 0.$$

At the first-best solution, the firm invests until the marginal cost of investment is equal to its marginal benefit (represented by the diminishing expected loss). The optimal levels of dividend, c^*, and investment, I^*, are jointly determined by:

$$\begin{cases} K'(I^*) + \beta p'(I^*)X = 0 \\ \beta(1+\beta)c^* = \beta(1+\beta)\bar{y} - K(I^*) - \beta p(I^*)X, \end{cases}$$

where this last equality is the bank's participation constraint. Hence, when the bank's surplus is zero, the firm's discounted dividend is equal to the firm's value.

3.2 The self-enforcing contract

We now derive the optimal financial contract assuming that the bank cannot commit to the contract. Bank liability is represented by the penalty k^s imposed to the bank in state (s, X). This penalty can depend on the state s because it should be possible for the legislator to make the bank's liability contingent on the firm's wealth. In particular, courts should be able to recover from the firm some of the damages before it appeals to the bank's contribution. For example, $k^s = X - y^s$ represents the case where the court seizes the firm's income, that is, it liquidates the firm, and makes the bank pay for the difference between y^s and X.

The penalty k^s affects the bank's autarcic opportunity because it is still liable to pay k^s even if it breaches the contract. Here, we assume that $k^s \in [0, X]$, therefore encompassing full ($k^s = X$ for all s), partial ($k^s < X$) or no liability ($k^s = 0$).

The optimal contract is the solution to the following maximization problem.

$$\max_{c_1^{sx}, c_2^z(s,x)} \beta(1-p(I))\mathrm{E}_s[u(c_1^{s0}) + \beta \mathrm{E}_z u(c_2^z(s,0))] + \beta p(I)\mathrm{E}_s[u(c_1^{sX}) + \beta \mathrm{E}_z u(c_2^z(s,X))]$$

$$\begin{aligned} \text{s.t.} \quad & -K(I) + \beta(1-p(I))\mathrm{E}_s[y^s - c_1^{s0} + \beta \mathrm{E}_z(y^z - c_2^z(s,0))] + \\ & \beta p(I)\mathrm{E}_s[y^s - X - c_1^{sX} + \beta \mathrm{E}_z(y^z - c_2^z(s,X))] \ \geq \ 0 \qquad (2) \\ & y^s - c_1^{s0} + \beta \mathrm{E}_z(y^z - c_2^z(s,0)) \geq 0 \qquad \forall s \in \mathcal{S} \qquad (3) \\ & y^s - X - c_1^{sX} + \beta \mathrm{E}_z(y^z - c_2^z(s,X)) \geq -k^s \qquad \forall s \in \mathcal{S} \qquad (4) \end{aligned}$$

Let us associate to constraint (2) the Lagrange multiplier λ, and to the set of constraints (3) and (4) for all $s \in \mathcal{S}$, the multipliers $\beta q^s \theta^{s0}$ and $\beta q^s \theta^{sX}$ respectively. The first-order conditions for this problem give an immediate result on the intertemporal smoothing of dividend.[9]

Proposition 1. *Whatever the liability rule, intertemporal smoothing of the firm's dividend is always perfectly achieved, that is, for all* $s \in \mathcal{S}$ *and all* $x \in \{0, X\}$*:* $c_2^z(s,x) = c_1^{sx} \quad \forall z$.

The contract always specifies that the dividend in period $t = 2$ depends only on the realization of period $t = 1$ state of nature. Full insurance is provided against shocks to the

[9] All proofs are relegated to the Appendix.

second period income because we assume that the bank can fully commit to second period transfers. We note $c_2^z(s,x) = c_1^{sx} = c^{sx}$ and rewrite the self-enforcing constraints:

$$y^s + \beta\bar{y} - (1+\beta)c^{s0} \geq 0 \;\text{ for all } s \in \mathcal{S}$$
$$y^s - X + \beta\bar{y} - (1+\beta)c^{sX} \geq -k^s \;\text{ for all } s \in \mathcal{S}.$$

Given this result on dividends, the first-order condition on investment is:

$$K'(I) + \beta p'(I)X = \frac{1}{\lambda}\beta p'(I)(1+\beta)\mathrm{E}_s(u(c^{sX}) - u(c^{s0})) - \beta p'(I)(1+\beta)\mathrm{E}_s(c^{sX} - c^{s0})$$

$$\Leftrightarrow \quad K'(I) + \beta p'(I)X = \beta p'(I)(1+\beta)\mathrm{E}_s\left\{\left(\frac{u(c^{sX})}{\lambda} - c^{sX}\right) - \left(\frac{u(c^{s0})}{\lambda} - c^{s0}\right)\right\}.$$

The liability rule does not influence directly the investment level. There is, however, an indirect effect. Bank liability affects risk-sharing which, in turn, influences the investment level. It is then important to characterize the solution for the dividends before we can solve for the optimal investment level.

3.2.1 Risk-sharing and dividends

First-order conditions for dividends are given by the following equations that hold for all s in $\mathcal{S}$.

$$u'(c^{s0}) = \lambda + \frac{\theta^{s0}}{1 - p(I)} \tag{5}$$

$$u'(c^{sX}) = \lambda + \frac{\theta^{sX}}{p(I)} \tag{6}$$

The bank liability's effect on risk-sharing implicitly appears through the multipliers θ^{sx}. A binding self-enforcing constraint in state (s,x) $(\theta^{sx} > 0)$ means that it is not possible for the bank to provide the firm with a dividend higher than c^{sx} which satisfies the self-enforcing constraint $y^s + \beta\bar{y} - (1+\beta)c^{s0} = 0$ or $y^s - X + \beta\bar{y} - (1+\beta)c^{sX} = -k^s$, without having the bank leaving the contract. A higher level of c^{sx} would actually make autarky more interesting for the bank. Then, depending on whether the self-enforcing constraint binds or not, the dividend may be limited by bank liability or not. If no self-enforcing constraint binds, the firm is perfectly insured and the solution is the same as in the full-commitment case.

The next proposition provides some basic properties of the optimal dividends.

Proposition 2. *Dividends c^{sx} are weakly increasing in $y^s - x + k^s \frac{x}{X}$.*

An optimal contract smooths dividends across states of nature as much as possible. This is achieved by having dividends lower than income in high income states and higher than it in low income ones when self-enforcing constraints allow it. These constraints can be written as $(1+\beta)c^{sx} \leq y^s - x + k^s x/X + \beta\bar{y}$.[10] The l.h.s. represents the dividend payment from the bank to the firm while the r.h.s. represents what the bank foregoes if it breaches the contract and does not refinance the firm. They are more likely to be binding for low levels of $y^s - x + k^s x/X$. Because of the contingent liability k^s, self-enforcing constraints do not necessarily bind in low income states $y^s - X$. When a self-enforcing constraint is binding, the dividend satisfies the expression with equality. For states in which the constraint is not binding, dividends are constant and (weakly) higher than the highest level for binding states. Dividends are then weakly increasing in $y^s - x + k^s x/X$. This result allows us to examine the effect of bank liability on dividends and risk-sharing.

Corollary 1. *1. With no bank liability, dividends are increasing with $y^s - x$;*

2. With full bank liability, $c^{s0} = c^{sX}$ for all s;

3. With partial bank liability, $c^{s0} \geq c^{sX}$ for all s.

This corollary follows directly from Proposition 2. In the first part, since $y^s - x + k^s x/X = y^s - x$ for $k^s = 0$, it is immediate that dividends increase with net income $y^s - x$. When there is full bank liability, that is, $k^s = X$ for all s, all self-enforcing constraints reduce to $(1+\beta)c^{sx} \leq y^s + \beta\bar{y}$. These are independent of x, which implies that $c^{s0} = c^{sX}$ for all s. With full bank liability, an environmental accident does not worsen the refinancing problem in period $t = 1$ as the bank has to pay for the environmental damage whether it breaches the contract or not. This implies that dividends are not affected by the occurrence of an accident. As soon as the bank becomes less liable, however, its self-enforcing constraints in accident states are more likely to become binding because the incentives to stay in the relationship are weaker. The firm then earns a (weakly) higher dividend when there is no accident than when there is one.

The next subsection uses the properties of optimal dividends to characterize the optimal period $t = 0$ investment.

[10] If $x = 0$, this reduces to $(1+\beta)c^{s0} \leq y^s + \beta\bar{y}$.

3.2.2 Investment

The insurance possibilities of the contract determine the firm's incentives to invest in environmental risk prevention. The next proposition shows that investment depends on the bank liability rule.

Proposition 3. *1. If there is partial, or no bank liability, the firm overinvests in the risk-reducing technology, compared to the full-commitment optimal level;*

2. If there is full bank liability, the firm invests at the full-commitment optimal level I^*.

We only provide here a sketch of the proof. The first-order condition for investment is:

$$K'(I) + \beta p'(I)X = \frac{1}{\lambda}\beta p'(I)(1+\beta)\mathrm{E}_s(u(c^{sX}) - u(c^{s0})) - \beta p'(I)(1+\beta)\mathrm{E}_s(c^{sX} - c^{s0})$$

The sign of the right-hand-side term determines the importance of the investment level I compared to the full-commitment optimal level I^* implicitly defined by $K'(I^*) + \beta p'(I^*)X = 0$. The right-hand-side term is directly related to the efficiency of risk-sharing between accident and no-accident states. We see immediately that full bank liability ($k^s = X$), which allows perfect insurance against environmental accident ($c^{s0} = c^{sX}$), entails an optimal level of investment as the first-order condition for investment becomes $K'(I) + \beta p'(I)X = 0$. As soon as insurance against states $x = X$ is not complete ($c^{s0} > c^{sX}$), the right-hand-side term is not zero, and the level I is different from I^*.

This result is very intuitive. In fact, the firm's incentives are directly related to the firm's wealth in each state of nature. When the firm is perfectly insured against accident states, it has no incentives to make special effort to avoid those states. The bank is risk neutral and, hence, cares only about expected firm value. Since the firm is perfectly insured against the accident, it behaves in a risk-neutral fashion with respect to the choice of the contractual investment level. The investment level is then calculated in order to reduce the risk of loss X that affects the firm's value, which yields the investment level I^*.

As soon as dividends cannot be perfectly smoothed between states of accident and no accident, however, the firm considers more than the reduction in firm's value entailed by an environmental accident. It supports a disutility due to the difference in dividends between different states and has an incentive to avoid states of low dividends. The firm then increases its investment in order to reduce the probability of accident. Since the overinvestment reduces the firm value compared to the full-commitment optimum, the bank reduces the firm's expected level of dividends. Since the firm is risk-averse, it is always willing to diminish marginally its level of dividends in exchange for a decrease in the risk it supports.

When the environmental accident does not cause the firm's bankruptcy, the exogenous introduction of bank liability in financial contracts relaxes the bank's self-enforcing constraints, therefore improving the firm's dividend smoothing. The better insured firm has lower incentives to reduce risk and, hence, it does not distort its investment as much. This makes the investment level closer to the full-commitment optimal one.

4 The bankruptcy case

In the preceding section, we suppose that there is no possibility of bankruptcy. Even after an accident, taking the damage costs into account, the firm value remains positive. We could, however, imagine that such an important accident would cause the firm's ex post value to be negative. In that case, the accident annihilates the expected surplus and autarky may become better than any form of contract with the firm (depending on the liability rule).

This is the case we analyze in this section, that is, we assume that $y^s - X + \beta\bar{y} < 0$ for all s. This means that whatever the firm's income, the occurrence of an accident yields a negative firm value. In the absence of bank liability, it is not possible to construct a self-enforcing contract in the accident states. Actually, the self-enforcing constraints should be written as (3) and (4), but the only way to keep the bank in the contract in states $x = X$, would be to have $c_1^{sX} + \beta \mathrm{E}_z c_2^z(sX) < 0$ in (4). Firm's limited liability prevents such a solution. The relationship then inevitably ends after an accident.

If there is a form of bank liability, it is possible to have the bank refinancing the firm after an accident in states s such that $y^s - X + k^s + \beta\bar{y} \geq 0$. Depending on the specification of $\{k^s\}_s$, this can be satisfied in some states and not in others. The contract would then end after an accident in those states s where it is not satisfied, and continue in the other states. As the problem must integrate constraints and transfers only for states in which the relationship continues, it is dependent on the form of the liability rule. In order to limit the number of specifications (that depend on exogenous specifications), we concentrate here only on the polar cases $k^s = 0$ (no bank liability) or $k^s = X$ (full bank liability) for all s. When $k^s = 0$ for all s, $y^s - X + k^s + \beta\bar{y} < 0$ and the contract ends following an accident. When

$k^s = X$ for all s, $y^s - X + k^s + \beta\bar{y} > 0$ and the bank always refinances the firm following an accident.

4.1 No bank liability

In the case where $k^s = 0$, the contract takes no account of the accident states. The optimal contract solves the following maximization problem.

$$\begin{aligned} &\max_{c_1^{s0}, c_2^z(s,0)} \beta(1-p(I))\mathrm{E}_s[u(c_1^{s0}) + \beta\mathrm{E}_z u(c_2^z(s,0))] + \beta p(I)(1+\beta)u(0) \\ \text{s.t.} \quad & -K(I) + \beta(1-p(I))\mathrm{E}_s[y^s - c_1^{s0} + \beta\mathrm{E}_z(y^z - c_2^z(s,0))] \geq \ 0 \\ & y^s - c_1^{s0} + \beta[\bar{y} - \mathrm{E}_z c_2^z(s,0)] \geq 0 \qquad \forall s \in \mathcal{S}. \end{aligned}$$

If we associate Lagrange multipliers λ and θ^{s0}, for all $s \in \mathcal{S}$, respectively to these constraints, the first-order conditions give for all s in $\mathcal{S}$:

$$c_2^z(s,0) = c_1^{s0} = c^{s0} \qquad \forall z \in \mathcal{S} \tag{7}$$

$$u'(c^{s0}) = \lambda + \frac{\theta^{s0}}{1-p(I)} \tag{8}$$

$$K'(I) + \beta(1+\beta)p'(I)\left\{\bar{y} + \mathrm{E}_s\left(\frac{u(c^{s0}) - u(0)}{\lambda} - c^{s0}\right)\right\} = 0. \tag{9}$$

The optimal contract is similar to that found in the preceding section. Self-enforcing constraints cannot bind all together. Constraints bind in higher-income states, and dividends are higher in those states. One can then write: $\lambda = u'(c^{S0}) \leq u'(c^{s0})$ for all s.

Conclusions about the effect of non-commitment on investment call for a comparison of the optimal I given by equation (9) with the level $\hat{I}$ obtained in the full-commitment environment.[11] In the full-commitment optimum, $\theta^{s0} = 0$ and the dividend is constant for all s. The optimal level of investment is $\hat{I}$ such that

$$K'(\hat{I}) + \beta(1+\beta)p'(\hat{I})\left\{\bar{y} + \left(\frac{u(c) - u(0)}{u'(c)} - c\right)\right\} = 0. \tag{10}$$

[11] Note that we consider here a full-commitment environment where the firm goes bankrupt in the same states as in the non-commitment case so that we can compare the two cases. This implies that the full-commitment optimum is now dependent on the liability rule, which was not the case in the preceding section.

The comparison between the investment levels that respectively solve (9) and (10) is ambiguous. We can show that there exist some specifications of the firm's utility function such that the self-enforcing contract involves overinvestment compared to the level an enforceable contract would entail.

Proposition 4. *If $K(\cdot)$ and $p(\cdot)$ are such that $K(I)/(1-p(I))$ is increasing in I, and if the firm's utility function is any concave function such that $(u(c)-u(0))/u'(c)-c$ is convex in c, then the self-enforcing contract involves (weak) overinvestment compared to the full-commitment optimal level $\hat{I}$.*

For most power functions K and exponential functions p, the ratio $K(I)/(1-p(I))$ is increasing. The condition imposed to that ratio is then sufficiently weak for the proposition to be general. The set of utility functions for which $(u(c)-u(0))/u'(c)-c$ is convex is quite large too. Any thrice differentiable, concave and increasing function such that $u''' \leq 0$ satisfies the condition. It is also convex for all HARA functions of the form $u(c) = (1-\gamma)/\gamma(ac/(1-\gamma)+b)^{\gamma}$ with $a > 0$, $\gamma \neq 1$ and $b \geq 0$ (which includes CARA as well as CRRA functions). Hence, for most commonly used utility functions, overinvestment weakly obtains at the solution of the self-enforcing contract. Overinvestment is strict if some self-enforcing constraint is binding.

4.2 Bank liability

Let us consider now the full bank-liability case. The bank has to pay X after an accident independently of what happens in the contract. Self-enforcing constraints in accident states are then:

$$y^s - X + \beta\bar{y} \geq c_1^{s0} + \beta \mathrm{E}_z c_2^z(s,X) - X \quad \forall s \in \mathcal{S}.$$

In all states, the bank has incentives to refinance the firm since $y^s + \beta\bar{y} > 0$. Since the firm does not go bankrupt after an accident, the resolution will be exactly the same as for the no-bankruptcy-full-liability case. When the bank's full liability prevents the bank from taking advantage of the firm's limited liability, the accident cost is fully internalized. The contract then has the form described in the preceding section when there is full bank liability. Hence, investment is at the (no-bankruptcy) full-commitment level I^*.[12]

[12]It should be clear that partial liability would produce an intermediate case between the two polar cases analyzed in this section.

4.3 Discussion

The effect of the introduction of bank liability in financial contracts when environmental accidents can involve bankruptcy can be seen in the comparison of investment levels with and without bank liability. We then compare the level $\bar{I}$ obtained from equation (9) (no liability) with I^* (full liability).

$$\begin{aligned} K'(\bar{I}) + \beta p'(\bar{I})X &= \beta p'(\bar{I})[X - (1+\beta)\bar{y}] + \\ & \quad \beta(1+\beta)p'(\bar{I})\mathrm{E}_s\left\{\left(\frac{u(0)}{u'(c^{S0})} - 0\right) - \left(\frac{u(c^{s0})}{u'(c^{S0})} - c^{s0}\right)\right\} \quad (11) \\ K'(I^*) + \beta p'(I^*)X &= 0. \quad (12) \end{aligned}$$

In the bankruptcy case, $(1+\beta)\bar{y} < X$, and the first term in the right-hand side of (11) is always negative. In the proof of Proposition 3 we show that the second term is positive. Hence, the sign of equation (11) is indeterminate. The total effect of bank liability on investment is ambiguous, the absence of bank liability entails either under- or overinvestment compared to I^*, the full bank liability investment.

Because the firm does not go bankrupt when full bank liability is introduced, the investment level I^* can be interpreted as the investment when there is no limited liability for the firm (X is fully internalized in the investment decision). The level $\bar{I}$ can then be interpreted as the limited liability investment level. The general intuition suggested in the literature is that limited liability reduces incentives to invest in environmental protection. Here, this is not necessarily the case. What is new in this model is the introduction of risk-averse behavior for the firm. The first term of equation (11) represents the general effect of limited liability, that is, bankruptcy possibilities after accidents reduce the considered loss from X to $(1+\beta)\bar{y}$, which reduces ex ante incentives to invest. The second term expresses the fact that the risk-averse firm being imperfectly insured against the accident (because its revenue falls to zero in that case) has an incentive to invest to avoid this state. The sum of these two opposite effects cannot be signed here but when X is not too high compared to $(1+\beta)\bar{y}$ and the firm is highly risk-averse, we may observe a greater investment in environmental prevention when there is no bank liability as compared to when the bank is fully liable.

5 Social optimum

We have shown that bank liability induces the efficient investment behavior as it relaxes its self-enforcing constraints in accident states. We also showed that a non-liable bank induces a higher investment than when it is liable. From a social point of view, one has to determine the socially optimal level of investment before deciding whether banks should be liable or not.

The level of investment I^* depends on the anticipated cost X of an accident. The loss X is what the bank and the firm view ex ante as the cost of damages for the risk they both recognize. It represents what they anticipate a court will ask for compensation after an accident, given that they both know what type of accident they are dealing with. A part of this cost can be calculated without error: it is the value of lost equipments and the actual cost of repair and clean-up entailed by the accident. The other part is an evaluation of the prejudice suffered by outside victims: it is the amount of money representing a “fair” compensation for the environmental losses due to the accident. Such compensation can cover losses which can be directly evaluated using market prices (as in the case of economic-activity losses for the fishery or tourism industry after an oil spill) and losses which cannot be directly evaluated due to the absence of relevant prices (as in the case of the disappearance of animal species or natural sites). There are then two problems for the calculation of compensation. First, the evaluation of losses can be based on statistical estimation which yields only an approximation of the true value. Second, if the loss has an impact in the future (it is still the case for the disappearance of animal species), it is necessary to agree on the choice of an appropriate discount rate.

The evaluation of non-market losses is usually based on the contingent valuation method that relies on the survey evaluation of the willingness to pay for the conservation of a particular environmental service (or the willingness to accept a compensation for the disappearance of that environmental service).[13] Statistical computations assign a value for environmental services from the estimated willingness to pay of the entire population. This method, however, involves a certain number of biases that make the measured cost imprecise. On top of the usual econometrics and aggregation biases, surveyed respondents often have a tendency

[13] It is the most common method because it even takes into account the evaluation of people who never use the environmental service. This is often called the “passive value”. For a description of that and other methods, see Hanley and Spash (1993).

to overstate their willingness to obtain compensation and to understate their willingness to pay. The contingent valuation method may then over- or underestimate the value of a particular environmental service and, hence, the monetary loss to be paid in compensation.

There is a debate among economists about the choice of an appropriate discount rate for evaluating environmental services.[14] The market rate of interest is generally used as the discount rate for evaluation of future contingencies. Weitzman (1994) argues, however, that the discount rate used should be lower than the marginal productivity of capital (the market rate of interest) because any reduction in today's consumption to finance investment and, hence, yield a greater production tomorrow, also entails a greater level of pollution. In that case, the resources that must be devoted to pollution reduction in the next period reduce the gains of investment in terms of future consumption, and therefore, the increase in future consumption is not as large as in a model with no environmental consideration. The discount rate used to evaluate projects with environmental concerns should then be lower than the marginal productivity of capital that is generally used for discounting. Weitzman's (1994) argument is based on the premise that some future costs in terms of pollution are not taken into account when evaluating projects with environmental concerns. This implicitly supposes that courts cannot correctly value the costs of environmental accidents when imposing compensating and punitive damages to polluters. In that case, compensation payments underestimate the environmental loss, that is, the real social cost is $X + A$ with $A > 0$. The socially optimal level of investment is then I^{**} such that:

$$K'(I^{**}) + \beta p'(I^{**})(X + A) = 0$$

where $I^{**} > I^*$.

If the social loss $X + A$ is large compared to the monetary loss X, the imposition of bank liability yielding investment I^* is not desirable as it keeps investment away from its socially efficient level. On the other hand, if banks are not liable, firms overinvest and, hence, may pick an investment level closer to I^{**}. In a more detailed model, one could determine the optimal level of bank liability as a function of A. For example, if the contractual investment I when there is no bank liability is larger than the socially optimal level I^{**}, the introduction of partial bank liability could become efficient. If I^{**} is known by the legislator, it is possible to calibrate the optimal degree of bank liability such that the bank and the firm agree to

[14] See Hanley and Spash (1993) for the argumentation about the discount rate for environmental evaluations.

invest exactly I^{**}. If A is low, however, $I^{**} \simeq I^*$, and bank liability is a good policy in that it improves the risk-sharing obtained by firms and keeps investment close to the socially efficient one.

We only make the point here that if courts underestimate the social costs of environmental accidents, bank liability may have unsuspected costs in terms of underinvestment in environmental protection. The legislator has to keep in mind that bank liability reduces the incentives for risk reduction investments. The legislator must then be aware of the difference between the compensation courts can impose ex post (X) and the real and unknown consequences of accidents ($X + A$).

6 Conclusion

Court judgments that followed the introduction of CERCLA actually justified the imposition of bank liability by the fact that banks had close and long relationships with firms and, hence, possibly an influence on their decisions. Firms and banks entering in contractual relationships take into account bank liability when writing contracts, and therefore, the consequences of past court decisions have an impact on environmental prevention.

When firms are risk averse, the usual limited liability investment reducing effect is mitigated by the will to smooth dividends through states of nature. Giving a part of the environmental risk to firms can then have a positive effect on their risk reducing behavior. Hence, even if environmental accidents cause bankruptcy, firms have an incentive to avoid the bankruptcy states and can invest more (in the absence of bank liability) than what risk-neutral firms with limited liability would do.

Laws such as CERCLA seek to apply the principle that polluters should pay for the pollution they generate. These laws then reduce the social burden of environmental risks in two ways: first, because compensation payments do not have to be supported by tax-payers' money; second, because they provide better incentives for prevention. If the search for a payer entails the legislator to turn against banks, however, the financial system can suffer distortions whose consequences on the pollution level are uneasily quantifiable. As is shown here, bank liability reduces the part of risk that firms incur (which is an efficient consequence) and their incentives to prevent such risks (which is an inefficient consequence), and this, even if investment inprevention is observable. Whether bank liability is a good policy or not depends in part on the evaluation courts make of the social costs of environmental accidents. The effects of bank liability characterized here have to be weighted against benefits in terms of monitoring and auditing of firms' prevention activities when such activities are not directly enforceable in a contract (see, for example, Boyer and Laffont, 1997).

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Appendix

Proof of Proposition 1:
The first-order conditions for dividends are:

$$\begin{aligned}
&(1-p(I))u'(c_1^{s0}) = (1-p(I))\lambda + \theta^{s0} \quad \forall s \\
&p(I)u'(c_1^{sX}) = p(I)\lambda + \theta^{sX} \quad \forall s \\
&(1-p(I))u'(c_2^{z}(s,0)) = (1-p(I))\lambda + \theta^{s0} \quad \forall z \\
&p(I)u'(c_2^{z}(s,X)) = p(I)\lambda + \theta^{sX} \quad \forall z.
\end{aligned}$$

These conditions clearly imply that $c_1^{sx} = c_2^z(s,x)$ for all z. Furthermore, they do not depend on the assumptions for k^s. *Q.E.D.*

Proof of Proposition 2:
Self-enforcing constraints imply that $(1-\beta)c^{sx} \leq y^s - x + k^s x/X + \beta\bar{y}$. The upper bound on dividends is then $(y^s - x + k^s x/X + \beta\bar{y})/(1-\beta)$. It is increasing in $Y^{sx} \equiv y^s - x + k^s x/X$. Suppose that there are two states such that $Y^{s'x'} > Y^{sx}$ with $c^{s'x'} < c^{sx}$. By first-order conditions, it cannot be the case that $\theta^{s'x'} = \theta^{sx} = 0$, since this would imply $c^{s'x'} = c^{sx}$. It cannot also be the case that $\theta^{s'x'} > 0$ and $\theta^{sx} > 0$, since dividends would be equal to their respective upper bound, and would thus be increasing in Y. Since $c^{s'x'} < c^{sx}$, it must therefore be the case that $\theta^{s'x'} > 0$ and $\theta^{sx} = 0$. But this implies that

$$c^{s'x'} = (Y^{s'x'} + \beta\bar{y})/(1-\beta) > (Y^{sx} + \beta\bar{y})/(1-\beta) \geq c^{sx},$$

a contradiction of our initial assumption. This proves that dividends are weakly increasing in $y^s - x + k^s x/X$. *Q.E.D.*

Proof of Corollary 1:

1. This follows directly from Proposition 2 when $k^s = 0$.
2. When $k^s = X$, $Y^{s0} = Y^{sX}$. Self-enforcing constraints are then the same in states $s0$ and sX. Both $\theta^{s0} = \theta^{sX} = 0$ or $\theta^{s0} > 0$ and $\theta^{sX} > 0$ imply $c^{s0} = c^{sX}$. Either assumption $c^{s0} > c^{sX}$ or $c^{s0} < c^{sX}$ leads to a contradiction.
3. This follows directly from Proposition 2 when $k^s \in (0, X)$.

Q.E.D.

Proof of Proposition 3:

1. We first show that $\theta^{S0}=0$. Suppose not. Then, $\theta^{sx}>0$ for all states (s,x) (since dividends are increasing in Y^{sx}. We can then characterize the dividend level in each state using self-enforcing constraints:

$$(1+\beta)c^{s0}=y^s+\beta\bar{y} \ \ \forall s$$
$$(1+\beta)c^{sX}=y^s-X+k^s+\beta\bar{y} \ \ \forall s.$$

Substituting dividends in the bank's participation constraint yields:

$$-\frac{K(I)}{\beta}-p(I)\mathrm{E}_s k^s<0.$$

For any values for $\{k^s\}_s$, the bank's participation constraint cannot hold if all self-enforcing constraints bind. Then, at least one self-enforcing constraint does not bind. Hence, $\theta^{S0}=0$ by Proposition 2. This implies that $u'(c^{S0})=\lambda$. The first-order condition for investment is then:

$$K'(I)+\beta p'(I)X=\beta(1+\beta)p'(I)\left\{\frac{\mathrm{E}_s[u(c^{sX})-u(c^{s0})]}{u'(c^{S0})}+\mathrm{E}_s(c^{s0}-c^{sX})\right\},$$

which implies:

$$K'(I)+\beta p'(I)X=\beta(1+\beta)p'(I)\mathrm{E}_s[(u(c^{sX})/u'(c^{S0})-c^{sX})-(u(c^{s0})/u'(c^{S0})-c^{s0})].$$

Define $f(c^{sx})=u(c^{sx})/u'(c^{S0})-c^{sx}$. Then, $f'(c^{sx})=u'(c^{sx})/u'(c^{S0})-1$.
Since $c^{S0}\geq c^{sx}$ for all (s,x), $u'(c^{sx})/u'(c^{S0})\geq 1$, and the function f is weakly increasing. Given $c^{sX}\leq c^{s0}$ we have $f(c^{sX})\leq f(c^{s0})$ for all $s\in\mathcal{S}$. It follows that:

$$K'(I)+\beta p'(I)X=\beta(1+\beta)p'(I)\mathrm{E}_s[f(c^{sX})-f(c^{s0})]\geq 0.$$

Since the l.h.s. is increasing, this implies that there is overinvestment compared to the full-commitment optimal level.

2. If there is full liability, $c^{sX}=c^{s0}$ for all s, and then $K'(I)+\beta p'(I)X=0$, which means that investment is at its full-commitment optimal level. *Q.E.D.*

Proof of Proposition 4:

Denote $c^{s0} = c^s$ for all s and remember that $\lambda = u'(c^S) \leq u'(c^s)$ for all s. Assume that $K(I)/(1-p(I))$ is increasing in I. The bank's participation constraint is binding at the optimum in the non-commitment problem, that is, $\beta(1+\beta)\mathrm{E}_s c^s + K(\bar{I})/(1-p(\bar{I})) = \beta(1+\beta)\bar{y}$, and in the full commitment problem: $\beta(1+\beta)c + K(\hat{I})/(1-p(\hat{I})) = \beta(1+\beta)\bar{y}$. Hence, $\beta(1+\beta)\mathrm{E}_s c^s + K(\bar{I})/(1-p(\bar{I})) = \beta(1+\beta)c + K(\hat{I})/(1-p(\hat{I}))$.

Now suppose that $\bar{I} < \hat{I}$. This implies $K(\bar{I})/(1-p(\bar{I})) < K(\hat{I})/(1-p(\hat{I}))$ since $K(I)/(1-p(I))$ is increasing, and then, $\mathrm{E}_s c^s > c$.

Since $(u(c)-u(0))/u'(c) - c$ is increasing and if it is convex, we have

$$\begin{aligned}\frac{u(c)-u(0)}{u'(c)} - c \quad &< \frac{u(\mathrm{E}_s c^s)-u(0)}{u'(\mathrm{E}_s c^s)} - \mathrm{E}_s c^s \\ &\leq \mathrm{E}_s[\frac{u(c^s)-u(0)}{u'(c^s)} - c^s] \leq \mathrm{E}_s[\frac{u(c^s)-u(0)}{u'(c^S)} - c^s]\end{aligned}$$

Then, evaluating equation (10) for the allocations $\{c^s\}$ gives

$$\frac{1}{\beta}K'(\hat{I}) + (1+\beta)p'(\hat{I})\left\{\bar{y} + \mathrm{E}_s\left(\frac{u(c^s)-u(0)}{u'(c^S)} - c^s\right)\right\} < 0.$$

That is, $\bar{I} > \hat{I}$ and this contradicts the initial assertion. Then it must be that $\bar{I} \geq \hat{I}$, that is, the self-enforcing contract involves overinvestment compared to the full commitment optimal level $\hat{I}$. *Q.E.D.*