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Centre interuniversitaire de recherche
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Série Scientifique
Scientific Series

Nº 94s-22

ENVIRONMENTAL RISKS AND BANK LIABILITY

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Montréal
Décembre 1994

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Les organisations-partenaires / The Partner Organizations

ISSN 1198-8177

ENVIRONMENTAL RISKS AND BANK LIABILITY*

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Revised: April 1995

* We thank David Martimort, Michel Poitevin, Jacques Robert and Alistair Ulph for their comments. Financial support from SSHRC (Canada), FFSA (France) and the Mattei Foundation (Italy) is gratefully acknowledged.

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ABSTRACT

Many governments have introduced or are considering introducing laws to recover from the *liable* parties the cleanup costs caused by pollution damages. In particular, the banks who finance the firms causing environmental damages may be considered liable. In various court cases in the US and elsewhere, banks have been found liable, while they have been exempted in others. We develop a multiprincipal-agent model in which the insurance sector may insure the firm for the pollution risk and the bank may lend money for investment. Under complete information of the bank about the firm's activities, the limited liability of the firm induces excessive investment and insufficient care but full liability of the bank creates the appropriate internalization of the environmental risk. This rationalization of the laws on lender liability must be qualified because in general the banks suffer from agency problems (adverse selection and moral hazard) in their relationships with firms. In the adverse selection case, full liability of the bank leads to underinvestment. Partial liability is better but may fail to implement the optimal second best allocation. In the case of moral hazard, full responsibility is killing the project too often while still leading to low care too often. Partial responsibility may achieve the second best optimal allocation but in some cases the level of responsibility necessary to induce the proper level of care is too high for the project to be financed by the bank. We conclude with a discussion of the implications of our results with regards to liability laws for environmental damages.

Keywords: Environmental Risk, Pollution, Lender Liability, Banking, CERCLA.

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RÉSUMÉ

Plusieurs gouvernements ont introduit ou pensent introduire des lois leur permettant de recouvrer les coûts de décontamination auprès des parties responsables de la pollution. Les banques des entreprises concernées peuvent, en particulier, être tenues responsables des dommages et elles l'ont effectivement été dans certains cas. Nous proposons ici un modèle principal-agent avec un secteur assurance et un secteur bancaire. Dans le cas où la banque possède une information complète des activités de l'entreprise, nous montrons que les règles de responsabilité limitée mènent à des niveaux d'investissement et de négligence trop élevés que peut par ailleurs corriger adéquatement la pleine responsabilisation de la banque. Cette rationalisation des lois sur la responsabilité des prêteurs doit être réexaminée car de manière générale, les banques font face à des problèmes d'agence [sélection adverse et risque moral] dans leurs relations avec les entreprises. Dans le cas de la sélection adverse, la pleine responsabilité de la banque mènerait à un sous-investissement dans les entreprises concernées. La responsabilité partielle est préférable mais peut s'avérer insuffisante pour implémenter la solution optimale de second rang. Dans le cas du risque moral, la pleine responsabilité de la banque entraînerait trop fréquemment le retrait de la banque et donc la non-réalisation du projet tout en n'assurant pas assez souvent le bon niveau d'effort dans la prévention d'accident environmental. La responsabilité partielle pourrait dans certains cas implémenter la solution optimale de second rang. Mais le niveau de responsabilité partielle nécessaire pour induire le bon niveau d'effort peut être trop élevé pour que le financement du projet soit profitable pour la banque. Nous concluons par une discussion des implications de nos résultats pour la détermination des règles de responsabilité en matière de dommages environmentaux.

Mots clés: risques environnementaux, pollution, responsabilité du prêteur, banque, CERCLA.

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1. INTRODUCTION

The polluter pay principle in the domain of environmental risks, and in particular pollution, is now widely accepted. Recently, efforts have focused on the difficulties encountered to fully compensate the pollutees because of an unidentifiable polluter, invalid insurance or limited liability for example. This has led in a first stage to the creation of funds financed by taxes, such as Fipa and Superfund, to guarantee a quick indemnification of the victims and quick depollution procedures. Germany has recently adopted a law in this direction [Umwelthaftungsgesetz, 1990] and several European countries have already such a system.[1] But little thought has been given to the incentive issues which can arise in this context in particular in view of the firms' limited liability constraints.

To mitigate the costs of these funds, the regulators have been given extended tools to recover cleanup costs from the liable parties. The most explicit example is CERCLA, the 1980 Comprehensive Environmental Response, Compensation and Liability Act in the US. CERCLA specifies that the parties responsible for cleanup costs following an environmental accident may include, among others, the current and past owners and operators of the facility. When a bank has been relatively closely involved in the supervision or monitoring of a firm's activities, it may be considered by the courts as an operator and therefore liable for cleaning up the damages.[2] In the court case of US v. Mirabile in 1985, the Mellon Bank was found liable for damages but the American Bank and Trust and the Small Business Administration also involved in financing the firm were not: the court found Mellon Bank liable because it was significantly more involved in supervising the operations of the firm. In the case of US v. Maryland Bank and Trust in 1986, the court found the bank, which held a mortgage on the property, liable for cleanup costs on the basis that, at the time the pollution damage was discovered, the

[1] See Smets (1992) for a discussion of these funds and Bianchi (1994) for an account of some recent developments.

[2] The meaning and limits of the security interest exemption rule have been largely discussed in view of apparently conflicting interpretations by the courts. See in particular Olexa (1991) and Strasser and Rodosevitch (1993).

bank was the owner of the facility that it had purchased at the foreclosure sale. Finally, in the case of US v. Fleet Factors Corporation in 1990-91, the bank was found liable for cleanup costs on the basis that its participation in the financial management of the firm gave it an "ability to influence" the overall management of the firm even if the bank was not involved in the operations of the firm.[3] As one could expect, this last case sent shock waves throughout the banking industry in the US and elsewhere.[4]

In England, the government has recently rejected calls from banks to be protected against the potential costs of cleaning industrial sites polluted by their corporate clients. In the new law being discussed, banks are likely to be made explicitly responsible when the companies they finance are found, even later on, to be responsible for pollution. The idea behind the stance is that banks can more effectively than regulators have an influence over managements: it is therefore more efficient to make them responsible for a company's pollution costs when the company cannot meet those costs, than to ask the regulators to set up costly and complex environmental protection schemes. In Canada, the polluter pay principle has been extended to a more general responsibility principle which makes liable for cleanup costs the owners and operators of the source of environmental damage. Although the laws remain partly unclear and the jurisprudence still fragmentary, it is believed by many legal experts that a bank may be considered among the operators even if it restricts its interventions to measures aimed at protecting its investments, loans or other financial interests. As in the US, the responsibility is in general retroactive, strict, joint and several.

These developments are affecting the banking industry by their effects on the availability of credit, the cost of capital and the structure of banking contracts for firms in

[3] For details of the judgment, see *Journal of Environmental Law* 4(1), 1992, 145-151.

[4] The controversy prompted the US Environmental Protection Agency to propose in April 1992 (originally proposed in June 1991) an interpretation, together with recommended tests, for the lender liability rule which provided considerable protection to lenders [see Staton (1993) and Manko and Neale (1994)]. However, the EPA's final rule was challenged, by the state of Michigan among others, in the U.S. Court of Appeals. In the 1994 case Kelly v. EPA, the court held that the EPA did not have the authority to affect the imposition of liability under CERCLA and rejected the EPA regulation as an interpretative rule [see Simons (1994)].

those industries which are sources of environmental risks. The banks have required that the firms they finance be insured against different types of accidents which can affect their solvency such as fire, theft and civil responsibility. They are likely to ask more and more for an extensive 'environmental audit' before financing a project, increasing the cost of bank lending. Are they going to ask that their corporate clients be insured against environmental damages, or will they prefer to insure their clients themselves?

This interaction between insurance and banking activities is just one example of a more general phenomenon. The "new" banking industry is becoming more and more an industry of risk management and its most pressing task may be to become significantly better at defining, managing and pricing risks.[5] The phenomenal developments in derivative assets markets and more generally in securitization[6] now allow banks to control and diversify, at a lower cost than before, the risks which their clients face or represent. They end up playing a role quite similar to insurers. This may make them willing and eager to compete for the traditional insurance business and also convince regulators to let them do it.

The question of the responsibility of the banks is particularly interesting in a period when the insurance and banking sectors are moving towards integration through *bancassurance* or *allfinanz*. The important recent surge in linking banking and insurance businesses either through the creation of wholly owned subsidiaries, through acquisitions, or through alliances or mergers seems to indicate that the movement is almost inevitable and is likely to accelerate as regulatory constraints are bound to disappear under market pressures. The movement towards holding banks liable, totally or partially, for the environmental damages of theirs clients provides a case where the pros and cons of such an integration can be discussed at the microeconomic level. Traditional arguments[7] relate to economies of scale and scope, network or distribution economies, market power (in the form of tie-in sales of mortgage and life insurance for example), growth potential,

[5] *The Economist* [1992.05.02, 1993.04.10].

[6] See Beaudry, Boyer and Poitevin (1993).

[7] See Hoschka (1994).

demographic factors, trends in savings, disintermediation, and also to large scale securitization allowing a reduction in the cost of financing pools of borrowers rather than individual borrowers as in traditional bank lending (a more recent phenomenon). We want to stress in this paper another factor, namely the importance of agency costs in banking and insurance, and to suggest the possibility of reducing them by coordinating insurance and banking contracts. Major agency problems both in banking and in insurance include adverse selection problems [the banker and the insurer want to elicit the firm's truthful revelation of profit levels] and moral hazard problems [the banker and the insurer want to induce their clients to make unobservable self-protection efforts to reduce the probability of accidents]. From this perspective, this paper is a contribution to the microeconomics of bancassurance.[8]

From a more theoretical perspective, this paper brings together two strands of the literature through the partial endogenization of firms' limited liability constraints. Until recently, the insurance literature has neglected the effect of agents' limited liability constraints on the demand for insurance; Landsberger and Meilijson (1993) is a rare exception. Limited liability constraints have been considered in the principal-agent literature [see Sappington (1983), and Demski, Sappington and Spiller (1988)] and in industrial organization [see Brander and Lewis (1989)] but these constraints are exogenous and ignore the role of banks in their determination. We have also witnessed recently the development of the theory of optimal financial contracts based on informational asymmetries [see Townsend (1979), Gale and Hellwig (1985) and Bolton and Scharfstein (1990)]. We will study in this paper the interaction between banking contracts which determine financial constraints and the behavior of firms in their choice of insurance and in their choice of safety activities.[9]

[8] Although we concentrate here on the environmental risks associated with bank loans to firms, there are many other circumstances under which banking contracts and insurance contracts interact. One example is the housing loans to households with compulsory insurance clauses. Another example is loans to business with insurance provisions.

[9] This paper is also related to the literature which has studied a particular type of externalities, namely negative externalities which appear only with some probability [see Koenig (1985) and Sandler and Sterbenz (1988)].

The organization of the paper and our main results are as follows. Section 2 is devoted to the presentation of the basic model which is a two-period model with investment in both periods and an effort variable affecting the probability of an environmental accident. This model will enable us to address two incentive issues raised by the lender liability rule under CERCLA.[10]

We analyze in section 3 the case where the firm's profit and effort are observed by the bank [perfect monitoring] but not by the insurance sector. The underlying assumption is that the bank has indeed invested, on the basis of a cost-benefit analysis not modeled here, in a monitoring technology which allows it to observe perfectly the activities of the firm; but the insurer has not done so, hence the difference in the information of the two principals. We show that if insurance is not compulsory, the firm will not want to become insured. This implies that the social cost of an accident will not be internalized. If insurance is compulsory, the social cost of an accident is internalized but we still may have an equilibrium with an inefficient level of effort because limited liability constraints may make an effort inducing insurance contract impossible [even if the insurance contract has preseance on the banking contract]. In the absence of compulsory insurance, the bank, even if it is in *de facto* control of the firm, may choose to enforce an inefficient [low] level of effort in accident prevention because of the limited liability constraints. Conditional on the level of effort, the bank lends more often than called for by the first best investment

[10] In the Court of Appeal's judgment in the U.S. v Fleet Factors case, Circuit Judge Kravitch wrote the following.

> "Our interpretation of the exemption may be challenged as creating *disincentives* for lenders to extend financial assistance to businesses with potential waste problems .... As a result the improper treatment of hazardous wastes could be perpetuated rather than resolved. These concerns are unfounded.
> Our ruling today should encourage potential creditors to investigate thoroughly the waste treatment systems and policies of potential debtors ... The risk of CERCLA liability will be weighted into the terms of the loan agreement. Creditors, therefore, will incur no greater risk than they bargained for and debtors, aware that inadequate hazardous waste treatment will have a significant adverse impact on their loan terms, will have powerful *incentives* to improve their handling of hazardous wastes. Similarly, creditors' awareness that they are potentially liable under CERCLA will *encourage them to monitor* the hazardous waste treatment systems and policies of their debtors and insist upon compliance with acceptable treatment standards as a prerequisite to continued and future financial support. ... Once a secured creditor's involvement with a facility becomes sufficiently broad that it can anticipate losing its exemption from CERCLA liability, it will have a strong incentive to address hazardous waste problems at the facility rather than studiously avoiding the investigation and amelioration of the hazard." (italics added)
> *Journal of Environmental Law* 4(1), 1992, page 149.

rule because the social cost of an accident is not internalized by the bank. We show also that first best levels of effort and lending may be achieved in this context by making the bank fully liable for damages or by making full insurance compulsory for the bank rather than for the firm, avoiding in this manner the limited liability constraints [assumed irrelevant for the bank].

We then consider, in section 4, a first case of asymmetric information between the bank and the firm, namely the adverse selection case in which the bank does not observe the level of profit but does observe the level of effort by the firm while the insurer remains uninformed of both the profit and the effort levels. We characterize the second best optimum benchmark for this case, as a function of the social cost of public funds. We then show that the propensity of the bank to lend in comparison with the social optimum depends basically on the balancing of two effects, the undervaluation of the externality on the one hand (leading to too much investment) and the undervaluation of the social value of the firm's rent (leading to too little investment). Full responsibility allows for a proper internalization of the externality but leads to insufficient lending. We characterize the partial level of responsibility which induces the appropriate (second best optimal) initial investment decision (however, the renewal of the investment in period 2 may be insufficient when the cost of public funds is low).

In section 5, we consider a second case of asymmetric information between the bank and the firm, namely the moral hazard case in which the bank does observe the level of profit but not the level of effort to prevent accidents. Again, we characterize the second best optimum benchmark for this second case. We show that the banking contract will be effort inducing less often than called for by the second best optimal rule and that, conditionally on the effort level, there is overlending by the bank. We show that making the bank fully liable for damages will not induce the optimal level of effort by the firm as often as called for by the second best optimal rule; moreover, conditionally on the level of effort, the bank lends less often than called for by the optimal rule. We then characterize the optimal level of responsibility of the bank. It induces the second best

when the project is valuable enough. If not, responsibility cannot induce effort without killing the project. Two instruments would then be necessary to reach the second best, a level of responsibility and a subsidy for investment. We conclude in section 6.

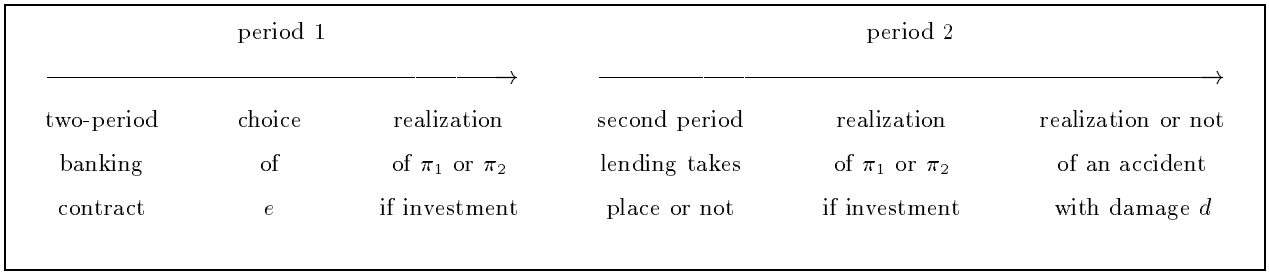
2. THE MODEL

We consider a two-period model with a risk neutral firm, a risk neutral bank and a competitive insurance sector. The firm has, each period, an investment opportunity which costs F and produces revenue π_1 with probability θ and revenue π_2 with probability $(1-\theta)$, with $\pi_1 < \pi_2$ and expected profit $\overline{\pi} = \theta\pi_1 + (1-\theta)\pi_2$. To keep the analysis as simple as possible, we assume that the stochastic revenues are independent from one period to the other and that the discount rate is zero.

By its choice of effort, $e \in \{0,1\}$, which has a [monetary] disutility ψ_e, with $\psi_0 < \psi_1$, the firm can affect the probability of an environmental accident which creates a damage $d > \pi_2$. Let p_0 and p_1 be respectively the probability of accident if the effort level is zero and one, with $p_0 > p_1$. For simplicity, we assume that effort is exerted in period 1 and that the accident occurs or not in period 2. All along the paper, we will assume that it is socially optimal in a first best sense to exert the effort level $e = 1$; in particular, under complete information, it means $\psi_1 - \psi_0 < (p_0 - p_1)d$.

The firm has no equity and its limited liability constraints will be essential. For simplicity, we focus on the case where, under complete information, the payment of a fair insurance premium for the environmental risk would never create a limited liability problem, that is $p_1 d < p_0 d < \pi_1$. At the beginning of period one, the bank and the firm negotiate a two-period loan contract. The insurer offers an insurance contract at the same time as the bank offers the financing contract. The timing of the interplay between the bank and the firm is as follows :

Figure 1



The main issue addressed in this model is the extent to which the limited liability constraint of the firm interferes with the externality problem. Note that the externality problem raises two issues, the issue of its internalization and the issue of the choice of an appropriate effort level. We examine the interaction of these various problems under several informational assumptions for the bank and the insurance sector and we discuss alternative economic policies.

3. FULL INFORMATION IN BANKING.

With risk neutrality, moral hazard variables can be controlled at no cost by appropriate penalties without having to give up any rent to the firm. When a limited liability constraint is added, it may be necessary to give up a rent to the firm. Effort is induced by rewards rather than penalties, which are bounded by the limited liability constraints. Here the behavior of the bank, which under full information can expropriate any rent the insurance sector might want to leave to the firm to induce effort, destroys not only any incentive for effort but also any incentive to buy insurance.

Under our assumptions, the full information first best allocation, which will be the welfare benchmark in this section, entails clearly[11] $e = 1$ and an investment in both periods if $2\overline{\pi} - 2F - p_1 d - \psi_1 > 0$.

3.1 *The Nash Equilibria*

The bank offers a contract which specifies, for loans of F at the beginning of each period, reimbursements R_1 [respectively R_2] at the end of period 1 if the profit level is π_1

[11] We are more explicit in section 4 about the social welfare function used.

[respectively π_2] in period 1 and R^1 [respectively R^2] at the end of period 2 if the profit level is π_1 [respectively π_2] in period 2. A bank contract can here be summarized by the 4-tuple (R_1, R_2, R^1, R^2). The bank is willing to offer a loan in both periods as long as its expected profit is non negative, that is as long as

$$\theta R_1 + (1-\theta)R_2 + (1-p_e)[\theta R^1 + (1-\theta)R^2] - 2F \geq 0 \tag{3.1}$$

If an accident occurs, the firm must pay for the damages, at least up to the maximal amount made possible by its limited liability. Since $d > \pi_2$, it means that all its profit will be taken away if an accident occurs.

The insurance sector which is competitive offers either a contract with a single premium $p_0 d$ paid in period 1 which fully insures the firm but induces no effort [$e = 0$] or a full insurance incentive contract which induces an effort level $e = 1$. For maximal flexibility, we assume that the premia can be spread over period 1, s_1, and period 2, s_2^1 or s_2^0, according to the occurrence or not of an accident which is the only observable of the insurance sector. To induce effort level $e = 1$, these premia must be such that:

$$s_2^1 - s_2^0 \geq \frac{\psi_1 - \psi_0}{p_0 - p_1}. \tag{3.2}$$

Because of limited liability and the fact that profit above π_1 is not observable by the insurer, they must satisfy:

$$s_1,\ s_2^0,\ s_2^1 \leq \pi_1. \tag{3.3}$$

Finally, because the insurance sector in competitive, they must satisfy the budget balance constraint:

$$s_1 + p_1 s_2^1 + (1-p_1)s_2^0 = p_1 d. \tag{3.4}$$

An incentive compatible balanced insurance contract can be summarized by $(s_1,\ s_2^0,\ s_2^1)$ satisfying (3.2), (3.3) and (3.4). We are interested in Nash equilibria of banking contracts, balanced insurance contracts and firm's decisions.

Proposition 1: *There exists no Nash equilibrium with voluntary insurance of the firm.* ‖[12]

Proof: All the proofs are given the appendix.

Is compulsory insurance the solution ? Compulsory full insurance creates the right internalization of the damage. Because of complete information and the fact that the firm's profit is completely expropriated in any Nash equilibrium, there exists no Nash equilibrium in which the firm is induced to exert effort level $e = 1$ (since as (3.2) indicates, such a contract must leave a rent to the firm in case of no accident). In the following, we will interpret compulsory full insurance as giving priority to the insurance contract over the banking contract. However, as the next proposition shows, there may not exist an equilibrium with compulsory insurance inducing effort since, because of its limited liability, the firm may not accept such a contract offered by the insurance sector.

Proposition 2: *If*

$$2\pi_1 < p_1 d + (1 - p_1)\frac{\psi_1 - \psi_0}{p_0 - p_1} \tag{3.5}$$

there exists no Nash equilibrium with compulsory insurance of the firm and $e = 1$*; but there is always a Nash equilibrium with compulsory insurance of the firm and* $e = 0$*, with lending if* $2\overline{\pi} > 2F + p_0 d + \psi_0$ *and without lending otherwise; conditionally on the level of effort, the level of lending is optimal.* ‖

Condition (3.5) can be rewritten as

$$\pi_1 + p_1\pi_1 + (1 - p_1)(\pi_1 - \frac{\psi_1 - \psi_0}{p_0 - p_1}) < p_1 d,$$

where the right hand side is the expected cost of an accident for the insurer and the left hand side is the maximal premium he can raise given limited liability constraints [the premium must be less than π_1 in all cases] and given the need for inducing effort [the wedge between the premium to be paid when there is an accident and when there is no accident must be $(\psi_1 - \psi_0)/(p_0 - p_1)$]. As the externality is now internalized, the bank's loan is optimal conditionally on the level of effort e [and therefore the bank lends less often when $e = 0$ than when $e = 1$].

[12] Note that this proposition is still valid if the insurance company has the same information as the bank.

3.2 *The Bank's Control and Liability*

Given that the firm does not want to become insured and that compulsory insurance is not always the solution because condition (3.5) may be satisfied for some projects, we may wonder if giving the bank the *de facto* control of the firm might be the solution. Will the bank request the firm to be insured before offering a loan? The answer is clearly no since the bank will indirectly benefit from the firm's limited liability and free ride on the compensation of the damage. Furthermore, we can obtain the condition under which, with no insurance, the bank imposes the optimal effort level. In all cases, the bank lends too often in any Nash equilibrium.

Proposition 3: *When it is in de facto control of the firm, the bank does not want the latter to buy insurance. It requires the firm to choose an effort level* $e = 1$ *iff* $\psi_1 - \psi_0 \leq (p_0 - p_1)\overline{\pi}$. *In all cases, the bank lends too often.* ‖

Since $\overline{\pi} < d$, the choice of $e = 1$ is made less often than called for by the first best rule. Furthermore, the bank lends too often because by the firm's limited liability it internalizes imperfectly the social cost of an accident.

To summarize the first three propositions, limited liability and the bank's expropriation of the firm's rent or profit destroys any incentive for the firm to buy insurance. Compulsory insurance of the firm may still lead to an insufficient level of effort to prevent an accident and putting the bank in *de facto* control of the firm alleviates but does not eliminate the internalization problem and therefore leads to overinvestment in the activities which create environmental risks. Would making the bank fully responsible for the firm's environmental damages be the solution?

Proposition 4: *With full liability of the bank or compulsory insurance of the bank, the full information first best allocation is achieved at a Nash equilibrium.* ‖

The bank's liability disposes of the firm's limited liability constraint. The bank now internalizes completely the externality and being risk neutral, it prefers the optimal level of effort $e = 1$ that it can require from the firm because of its perfect monitoring of the

firm's activities. This solution is equivalent to compulsory insurance of the bank despite the insurance sector's incomplete information. This is because the bank's risk neutrality and the assumed absence of [relevant] limited liability for the bank would enable the insurance sector to offer a balanced incentive compatible contract.

Given the above results, one may suggest that the proper solution to the full internalization of the externality created by environmental accidents is to make the banks fully responsible for damages if a firm they finance is found liable for cleanup costs. As we will see in the next section, when the bank suffers from agency problems in its relationship with the firm, possibly because it chose not to invest in a monitoring technology which would allow the observations of the firm's activities, this conclusion must be qualified.

4. ADVERSE SELECTION IN BANKING

We suppose now that the firm's effort is observable by the social regulator and the bank but that they both face an adverse selection problem regarding the future level of the firm's profit.[13] As for the insurer, he observes neither profit nor effort. We assume in this section that the optimal level of effort in that context is always $e = 1$ and that this level of effort is enforced by the social regulator. We characterize first the social optimum to be used as benchmark in this section, then the multiprincipal Nash equilibria and finally we derive the level of responsibility which induces the bank to lend if and only if it is second best optimal to do so.

4.1 *The Social Optimum under Adverse Selection.*

Because of asymmetric information, the full information first best allocation is not achievable anymore. The proper benchmark for our analysis is the optimum under adverse selection. We will assume that there is a cost $(1 + \lambda)$ of public funds[14] and

[13] Profits are typically difficult to observe. Not so much because they can be hidden in secret bank accounts but rather because they can be diluted in subtle ways through different forms of organizational inefficiencies, through 'superfluous' perks or activities and through transfer payments to associated companies.

[14] This cost comes essentially from distortions due to taxation: it cost $(1+\lambda)T$ to raise T through taxes. The value of λ is non-negligible and considered to be of the order of 0.3 in developed countries and higher in developing ones. See Jones, Tandon and Vogelsang (1990, chapter 3) for a recent review of the empirical evidence.

that the social welfare function [SWF] is utilitarian. Since the payments made by the firm to the bank can be assumed to be observable by the social regulator and that the cost F is common knowledge, it means that the profit of the bank is itself observable by the social regulator. Therefore, that profit could be taxed, possibly in a lump sum fashion, to reduce the social cost of distortions due to taxation. Hence, the bank's profit enters the social welfare function as $(1+\lambda)$ times that profit. If, as it will be the case here, the firm's utility is not observable by the regulator, this utility enters the social welfare function with a weight of 1.[15] Finally, the expected social cost of an accident will appear as that cost times $(1+\lambda)$ under the assumption that the consumers will be reimbursed by the government for the negative externality which the cost of an accident represents for them.

From the revelation principle, the social optimum is defined as the maximum of the expected social welfare under the incentive and the limited liability constraints of the firm [which is the only agent to have private information] and the individual rationality constraint of the firm.

Clearly, whatever the level of profit realized in period 2, the firm will always pretend that π_1 has been realized. As for the level of profit in period 1, the social regulator wants to elicit its truthful revelation to reduce the rent of the firm; he may be able to do so by making the probability of renewing the loan in period 2, which is the only instrument he has, dependent on the level of profit revealed in period 1 and by making payments in period 2 dependent also on the level of profit revealed in period 1.[16] Let β_i be the probability that the firm will be financed by the bank in period 2 if $\pi_i \in \{\pi_1, \pi_2\}$ is revealed in period 1. As before, let R_i and R^i be the payments to be made by the firm in period 1 and period 2 if $\pi_i \in \{\pi_1, \pi_2\}$ is revealed in period 1. Accordingly, the incentive constraint, the limited liability constraints and the individual rationality constraint of

[15] More generally, we could assume that a portion k of the bank's profit Π_B can be so observed and captured by the social regulator in which case, the bank's profit would enter the social welfare function as $(1+\lambda)k\Pi_B + (1-k)\Pi_B$.

[16] This context is quite similar to Bolton and Scharfstein (1990).

the firm are

$$\pi_2 - R_2 + \beta_2(\overline{\pi} - R^2) \geq \pi_2 - R_1 + \beta_1(\overline{\pi} - R^1) \tag{4.1}$$

$$\left.\begin{array}{c} R_1 \leq \pi_1 \ , \ R_2 \leq \pi_2 \\ R^1 \leq \pi_1 - R_1 + \pi_1 \ , \ R^2 \leq \pi_2 - R_2 + \pi_1 \end{array}\right\} \tag{4.2}$$

$$\theta[\pi_1 - R_1 + \beta_1(\overline{\pi} - R^1)] + (1-\theta)[\pi_2 - R_2 + \beta_2(\overline{\pi} - R^2)] - \psi_1 \geq 0. \tag{4.3}$$

The profit of the bank is given by the following, assuming that the payments by the firm are made even when an accident occurs:[17]

$$-F + \theta[R_1 + \beta_1(R^1 - F)] + (1-\theta)[R_2 + \beta_2(R^2 - F)]. \tag{4.4}$$

The social welfare function can be written as

$$\begin{aligned}(1+\lambda)\big[&-F + \theta[R_1 + \beta_1(R^1 - F)] + (1-\theta)[R_2 + \beta_2(R^2 - F)] - p_1 d\big] \\ &+ \big[\theta[\pi_1 - R_1 + \beta_1(\overline{\pi} - R^1)] + (1-\theta)[\pi_2 - R_2 + \beta_2(\overline{\pi} - R^2)]\big] - \psi_1\end{aligned}$$

that is as

$$\begin{aligned}(1+\lambda)\big[&(\overline{\pi} - F)(1 + \theta\beta_1 + (1-\theta)\beta_2 - p_1 d)\big] \\ &- \lambda\big[\overline{\pi} - \theta R_1 - (1-\theta)R_2 + \theta\beta_1(\overline{\pi} - R^1) + (1-\theta)\beta_2(\overline{\pi} - R^2)\big] - \psi_1.\end{aligned}$$

It increases with R_1, R_2, R^1 and R^2 and therefore letting $R^1 = R^2 = \pi_1$,[18] we obtain from the incentive compatibility constraint (4.1), $R_2 = R_1 - \beta_1(\overline{\pi} - \pi_1) + \beta_2(\overline{\pi} - \pi_1)$ which, when

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[17] This assumption has no effect on the characterization of the second best optimum since both the bank's profit and the cost of an accident have the same weight in the social welfare function.

[18] That $R^1 = R^2 = \pi_1$ is part of a social optimum can be shown, as in Bolton and Scharfstein (1990), as follows. Substituting (4.1) in the social welfare function, we obtain

$$(1+\lambda)\Big[(\overline{\pi} - F)(1 + \theta\beta_1 + (1-\theta)\beta_2)\Big] - \lambda\Big[\overline{\pi} - R_1 + \beta_1(\overline{\pi} - R^1)\Big] - \psi_1.$$

It increases with β_2 and therefore $\beta_2 = 1$ and only the sum $(R_2 + R^2)$ matters. Maximizing the social welfare function with respect to R_1 and R^1 leads to maximizing $R_1 + \beta_1 R^1$ subject to the limited liability constraints (4.2) and the individual rationality constraint (4.3); if (4.3) is not binding, then $R_1 = R^1 = \pi_1$ since $\beta_1 \leq 1$; if it is binding, then $R^1 = \pi_1$ and $R_1 = \overline{\pi} - \psi_1 + \beta_1(\overline{\pi} - \pi_1)$.

substituted in the individual rationality constraint (4.3), leads to $R_1 \leq \overline{\pi} - \psi_1 + \beta_1(\overline{\pi} - \pi_1)$. Hence, using the limited liability constraints (4.2), we have

$$R_1 = \min\{\pi_1,\ \overline{\pi} - \psi_1 + \beta_1(\overline{\pi} - \pi_1)\}.$$

If $\min\{\pi_1,\ \overline{\pi} - \psi_1 + \beta_1(\overline{\pi} - \pi_1)\} = \pi_1$, then the individual rationality [IR] constraint is not binding since the limited liability [LL] constraint prevents the social regulator from making it binding. If $\min\{\pi_1,\ \overline{\pi} - \psi_1 + \beta_1(\overline{\pi} - \pi_1)\} = \overline{\pi} - \psi_1 + \beta_1(\overline{\pi} - \pi_1)$, then the individual rationality [IR] constraint is binding in which case the social regulator cannot capture the firm's total profit when profit is low. Whether the IR constraint is binding or not depends not only on the parameters (π_1, π_2, ψ_1) but also on the chosen value of β_1. To illustrate the difficulties or inefficiencies that full banking responsibility leads to in this context of asymmetric information, we will assume that $\psi_1 < \overline{\pi} - \pi_1$ and therefore concentrate on the more interesting subcase in which the individual rationality constraint of the firm is never binding because the limited liability constraints will be binding first.[19] Hence $R_1 = \pi_1$, $R^1 = R^2 = \pi_1$, $R_2 = \pi_1 - \beta_1(\overline{\pi} - \pi_1) + \beta_2(\overline{\pi} - \pi_1)$ Substituting into the individual rationality constraint (4.3) and in (4.4), we obtain the rent $\mathcal{R}(\beta_1, \beta_2)$ captured by the firm under asymmetric information and the bank's profit $\Pi_B(\beta_1, \beta_2)$ as functions of the characteristics of the refinancing rule $(\beta_1,\ \beta_2)$.

$$\begin{aligned} \mathcal{R}(\beta_1, \beta_2) &= (1-\theta)(\pi_2 - \pi_1) + \beta_1(\overline{\pi} - \pi_1) - \psi_1 = (1+\beta_1)(\overline{\pi} - \pi_1) - \psi_1 \\ \Pi_B(\beta_1, \beta_2) &= \pi_1(1+\beta_1) + (1-\theta)\overline{\pi}(\beta_2 - \beta_1) - F(1 + \theta\beta_1 + (1-\theta)\beta_2) \end{aligned} \tag{4.5}$$

The firm's rent is independent of β_2 since the payment R_2 made by the firm includes $\beta_2(\overline{\pi} - \pi_1)$, the value for the firm of being refinanced. The social welfare function can be rewritten as a function of the refinancing rule

$$\begin{aligned} W(\beta_1, \beta_2) &= (1+\lambda)(\Pi_B - p_1 d) + \mathcal{R}(\beta_1, \beta_2) \\ &= (1+\lambda)\big[(\overline{\pi} - F)(1 + \theta\beta_1 + (1-\theta)\beta_2) - p_1 d - \psi_1\big] - \lambda\mathcal{R}(\beta_1, \beta_2). \end{aligned}$$

[19] In the framework of Bolton and Scharfstein (1990), there is no effort variable, that is $p_0 = p_1 = 0$ and $\psi_0 = \psi_1 = 0$, and the limited liability constraints (4.2) imply that the individual rationality constraint (4.3) is always met. Such is not the case in general when we introduce the cost of effort; hence our assumption that $\psi_1 < \overline{\pi} - \pi_1$.

Maximizing social welfare over β_1 and β_2, we obtain:

Proposition 5: *If $\psi_1 < \overline{\pi} - \pi_1$, then there exists $\hat{\lambda}$ defined by*

$$(1+\hat{\lambda})\theta(\overline{\pi} - F) = \hat{\lambda}(\overline{\pi} - \pi_1)$$

such that the socially optimal investment rules are as follows:

- *If $\lambda > \hat{\lambda}$, then $\beta_1 = 0$, $\beta_2 = 1$ and lending occurs in period 1 iff*

$$(2-\theta)(\overline{\pi} - F) - p_1 d - \psi_1 - \frac{\lambda}{1+\lambda}\mathcal{R}(0,1) > 0 \tag{4.6}$$

that is iff

$$(2-\theta)(\overline{\pi} - F) - p_1 d - \psi_1 + \lambda(\Pi_B - p_1 d) > 0 \tag{4.6'}$$

- *If $\lambda < \hat{\lambda}$, then $\beta_1 = \beta_2 = 1$ and lending occurs in period 1 iff*

$$2\overline{\pi} - 2F - p_1 d - \psi_1 - \frac{\lambda}{1+\lambda}\mathcal{R}(1,1) > 0 \tag{4.7}$$

that is iff

$$2\overline{\pi} - 2F - p_1 d - \psi_1 + \lambda(\Pi_B - p_1 d) > 0. \quad \| \tag{4.7'}$$

Intuitively, if $\lambda > [<]\hat{\lambda}$, the social loss due to the cancellation of the project in period 2 if π_1 is realized in period 1, $(1+\lambda)\theta(\overline{\pi} - F)$, is smaller [larger] than the social gain coming from a reduction of the second period expected rent through the cancellation of the project in period 2, $\lambda(\overline{\pi} - \pi_1)$. Accordingly, the project is cancelled, that is $\beta_1 = 0$ if $\lambda > \hat{\lambda}$ and refinanced if $\lambda < \hat{\lambda}$. The social welfare function is always increasing in β_2, since the rent left to the firm is independent of β_2, and therefore $\beta_2 = 1$. First period lending occurs whenever the social value of the project [either $(1+\lambda)\big(2(\overline{\pi} - F) - p_1 d - \psi_1\big)$ when $\lambda < \hat{\lambda}$ and $\beta_1 = \beta_2 = 1$, or $(1+\lambda)\big((2-\theta)(\overline{\pi} - F) - p_1 d - \psi_1\big)$ when $\lambda > \hat{\lambda}$ and $\beta_1 = 0$ and $\beta_2 = 1$] is larger than the social cost of the rent $\lambda\mathcal{R}(\beta_1, \beta_2)$. In other words, if the individual rationality constraint is not binding no matter what the investment policy chosen is, that is if ψ_1 is small enough [less than $\overline{\pi} - \pi_1$], then a rent is always left to the

firm and the socially optimal investment rule depends on the social cost of public funds. If that cost is high [$\lambda > \hat{\lambda}$], the social cost of the firm's rent is high and therefore the social regulator wants to keep it at a minimum; this implies, under asymmetric information, that investment takes place in period 2 only if profit is high in period 1 in order for payments made by the firm seeking refinancing in period 2 to depend on the realized level of profit in period 1. The profit of the bank net of the expected cost of an accident may be positive or negative, hence the no lending decision if the social cost of public funds λ is sufficiently larger than $\hat{\lambda}$ when the bank's profit is negative; for such large values of λ, $(4.6')$ is negative. If the social cost of public funds is low [$\lambda < \hat{\lambda}$], the socially optimal investment rule is to invest in both periods or not at all. Since $\beta_1 = \beta_2 = 1$, we have $R_2 = R_1 = \pi_1$ and the payments made by the firm are independent of the realized level of profit; the firm will get a rent of $2(\overline{\pi} - \pi_1) - \psi_1$. The profit of the bank net of the expected cost of an accident is $2(\pi_1 - F) - p_1 d < 0$, hence the no lending decision if the social cost of public funds λ is large enough to make $(4.7')$ negative.

4.2 *The Multiprincipal Equilibria under Adverse Selection.*

We are in the same situation as in the previous section regarding the position and role of the insurer: there will be no Nash equilibrium in which the firm voluntarily buys an insurance contract. Similarly, an insurance contract made compulsory for the firm may not induce the proper level of effort. Therefore, we can concentrate on the case with no insurance.[20]

Given that the bank cannot observe the level of profit, it cannot offer a financial contract which would make the level of payments dependent on the level of realized profit; it could only depend on the reported level. We assume that the bank's preferred level of effort in that context is also $e = 1$ [that is as we will see $(\psi_1 - \psi_0) < (1 - \theta)(p_0 - p_1)\pi_1$]. In the spirit of Bolton and Scharfstein (1990), the financial contract offered maximizes the expected profit of the banker $E\hat{\Pi}_B$ [which now is defined under the assumption that

[20] Compulsory insurance of the bank would lead here to the same result as full responsibility of the bank considered below.

if an accident occurs in period 2, no payment is made to the bank], that is

$$E\hat{\Pi}_B = -F + \theta[R_1 + \beta_1((1-p_1)R^1 - F)] + (1-\theta)[R_2 + \beta_2((1-p_1)R^2 - F)] \quad (4.8)$$

subject to the firm's incentive compatibility constraint (4.1), limited liability constraints (4.2) and individual rationality constraint (4.3).

The characterization of the financial contract offered by the bank follows lines similar to the characterization of the second best optimal contract except that, contrary to the social regulator, the bank does not take into account the social value of the firm's rent and that the bank does not receive the payments R^1 and R^2 when an accident occurs. Nevertheless the financial contract, if offered by the bank, will specify $R^1 = R^2 = \pi_1$ [payments in period 2 are maximal under the limited liability constraints], $\beta_1 = 0$ [no refinancing if π_1 is realized in period 1], $\beta_2 = 1$ [refinancing with certainty if π_2 is realized in period 1], $R_1 = \min\{\pi_1,\ \overline{\pi} - \psi_1\} = \pi_1$ [by the limited liability and the individual rationality constraints and the assumption $\psi_1 < \overline{\pi} - \pi_1$] and $R_2 = \min\{\overline{\pi},\ 2\overline{\pi} - \pi_1 - \psi_1\} = \overline{\pi}$ [by the incentive compatibility and limited liability constraints and the assumption $\psi_1 < \overline{\pi} - \pi_1$].[21] This contract can be interpreted as a loan contract with a refinancing covenant as follows: the bank lends F in period 1 and the firm must pay $\overline{\pi}$, in which case it is refinanced for an amount F in period 2 at the end of which the firm pays π_1 if no catastrophic accident occurs; if the firm's profits are too low in period 1, that is if profit is π_1, then the firm goes bankrupt, in which case the bank seizes the firm's observable profit π_1. The bank will lend whenever its expected profit is non-negative, that is whenever

$$E\hat{\Pi}_B = \theta\pi_1 + (1-\theta)\overline{\pi} + (1-\theta)[(1-p_1)\pi_1 - F] - F \geq 0. \quad (4.9)$$

[21] The proof that this contract solves the bank's problem can be shown as follows. From (4.1) we get $R_2 = R_1 - \beta_1(\overline{\pi} - \pi_1) + \beta_2(\overline{\pi} - \pi_1)$ and therefore from (4.2) and (4.3), $R_1 = \min\{\pi_1,\ \overline{\pi} - \psi_1 + \beta_1(\overline{\pi} - \pi_1)$. That $R^1 = R^2 = \pi_1$ is part of an optimal financial contract can be shown as in the proof of proposition 5. Substituting in (4.8) we find

$$E\hat{\Pi}_B = -F + R_1 + \beta_2(1-\theta)(\overline{\pi} - F - p_1\pi_1) + \beta_1\Big[\theta F + (1-\theta)\overline{\pi} - \pi_1[\theta(1-p_1) - (1-\theta)]\Big]$$

which implies $\beta_1 = 0$ and $\beta_2 = 1$ for both possible values of R_1. Using $\beta_1 = 0$ and $\beta_2 = 1$, we obtain $R_1 = \min\{\pi_1,\ \overline{\pi} - \psi_1\}$ and $R_2 = \min\{\overline{\pi},\ 2\overline{\pi} - \pi_1 - \psi_1\}$. If $\psi_1 < \overline{\pi} - \pi_1$, the individual rationality constraint is not binding but the first limited liability constraint is binding. Therefore $R_1 = \pi_1$ and $R_2 = \overline{\pi}$.

Proposition 6: *If $\lambda > \hat{\lambda}$, the bank, when it lends in period 1, lends in period 2 as often as called for by the optimal refinancing rule. If $\lambda < \hat{\lambda}$, the bank, when it lends in period 1, underinvests in period 2 since $\beta_1 = 0$ while $\beta_1 = 1$ is called for by the optimal refinancing rule.* ‖

As we already noted, for a high cost of public funds and therefore a low social valuation of the firm's utility level, the social optimum calls for the cancellation, for incentive reasons, of the renewal of the lending contract when π_1 is realized in period 1, exactly as the bank does since it faces the same incentive constraint. However, when the social cost of public funds is low, the social optimum calls for the realization of the second period project more often than the bank does because the social optimum program gives a higher value to the rent captured by the firm.

Proposition 7: *The bank lends less often in period 1 than the social regulator*

- *when $\lambda > \hat{\lambda}$, if*

$$p_1(d - (1-\theta)\pi_1) < \frac{1}{1+\lambda}\mathcal{R}(0,1); \tag{4.10}$$

- *when $\lambda < \hat{\lambda}$, if*

$$\begin{aligned} p_1(d - (1-\theta)\pi_1) &< \frac{1}{1+\lambda}\mathcal{R}(0,1) + \left[\theta(\overline{\pi} - F) - \frac{\lambda}{1+\lambda}\big(\mathcal{R}(1,1) - \mathcal{R}(0,1)\big)\right] \\ &= \frac{1}{1+\lambda}\big(\mathcal{R}(0,1) + \big[(1+\lambda)\theta(\overline{\pi} - F) - \lambda(\overline{\pi} - \pi_1)\big]\big) \quad \| \end{aligned} \tag{4.11}$$

When $\lambda > \hat{\lambda}$, the refinancing rule is the same in the equilibrium and in the social optimum, hence the rent is similar and equal to $\mathcal{R}(0,1)$. The bank lends less often than optimally when the undervaluation of the cost of the externality, $p_1\,(d - (1-\theta)\pi_1)$, is less than its overvaluation of the cost of giving up the rent to the firm, $\mathcal{R}(0,1) - \frac{\lambda}{1+\lambda}\mathcal{R}(0,1) = \frac{1}{1+\lambda}\mathcal{R}(0,1)$. The first factor favors overinvestment while the second favors underinvestment. When $\lambda < \hat{\lambda}$, the refinancing rule used by the bank differs from the socially optimal refinancing rule. Then the informational rent captured by the firm is higher in the social optimum, $\mathcal{R}(1,1) = 2(\overline{\pi} - \pi_1) - \psi_1$, than in the equilibrium, $\mathcal{R}(0,1) = \overline{\pi} - \pi_1 - \psi_1$. The bank lends less often than called for by the social optimum

if its undervaluation of the cost of the externality, $p_1\,(d-(1-\theta)\pi_1)$ is smaller than its overvaluation of the cost of giving up the rent $\mathcal{R}(0,1)$ to the firm *plus* the difference between the forgone surplus induced by its refinancing policy, $\theta(\overline{\pi}-F)$, and the social value of the firm's rent differential between the optimal refinancing policy and its own, $\mathcal{R}(1,1)-\mathcal{R}(0,1)$. The additional term is positive, by definition of $\hat{\lambda}$, when $\lambda<\hat{\lambda}$. Hence, the bank is more likely to underinvest when the social cost of public funds is small than it is when this cost is large.

4.3 *The Bank's Liability under Adverse Selection.*

Imputing full responsibility for environmental damage to the bank would be excessive and would lead in period 1 to insufficient lending. For large λ, the bank renews the lending contract in period 2 as often as called for by the second best optimum but, although the externality is now properly internalized, it remains that the bank underestimates the social value of the firm's rent and does not lend often enough in period 1.[22] For small λ, the second best optimum calls for the renewal of the lending contract while the bank renews it only if π_2 is realized in period 1. The proper internalization of the externality does not help solving this second period inefficiency and again leads to insufficient lending.[23]

In both cases, an appropriate partial internalization of the externality can lead to the proper first period lending level. If we require that the bank pays δd if an accident occurs, then, replacing $(1-\theta)p_1\pi_1$ by $p_1\delta d$ in (4.9) and comparing the new decision rule of the bank with the optimal investment rules given by (4.7) and (4.6),[24] we obtain:

[22] Condition (4.10) reduces to $0<\frac{1}{1+\lambda}\mathcal{R}(0,1)$ which is always satisfied.

[23] Condition (4.11) reduces to $0<\frac{1}{1+\lambda}\Big(\mathcal{R}(0,1)+\Big[(1+\lambda)\theta(\overline{\pi}-F)-\lambda(\overline{\pi}-\pi_1)\Big]\Big)$ which, by definition of $\hat{\lambda}$, is satisfied when $\lambda<\hat{\lambda}$.

[24] Alternatively, we can determine δ from (4.11) and (4.10) by replacing $(1-\theta)\pi_1$ by δd in both cases and the $<$ sign by the $=$ sign.

If $\lambda > \hat{\lambda}$,

$$\delta = \delta_1 = 1 - \frac{1}{(1+\lambda)p_1 d}\mathcal{R}(0,1) \tag{4.12}$$

If $\lambda < \hat{\lambda}$,

$$\delta = \delta_2 = 1 - \frac{1}{(1+\lambda)p_1 d}\big(\mathcal{R}(0,1) + \big[(1+\lambda)\theta(\overline{\pi} - F) - \lambda\big(\mathcal{R}(1,1) - \mathcal{R}(0,1)\big)\big]\big) \tag{4.13}$$

Clearly, $\delta_2 < \delta_1 < 1$. In the case of a low cost of public funds, the responsibility of the bank induces the second best lending decision in period 1 but lending in period 2 still does not take place when π_1 is realized in period 1 contrary to the second best optimal rule. The bank which dislikes, more than the social regulator, giving up a rent to the firm creates a more important inefficiency distortion in the lending rule to mitigate the informational rent which is more costly to the bank than to the social regulator. The social regulator would favor no distortion [because λ is small] but, in determining the optimal level of responsibility, must take as given the structure of the contract chosen by the bank. Summarizing, we have:

Proposition 8: *Full responsibility induces insufficient lending in period 1. Partial responsibility defined by a payment δd induces the optimal first period lending rule if $\delta = \delta_1$ for $\lambda > \hat{\lambda}$, achieving the second best, and if $\delta = \delta_2 < \delta_1$ for $\lambda < \hat{\lambda}$, in which case it remains that the bank does not renew the contract often enough (it renews it only when π_2 is realized in period 1).* ‖

Partial responsibility level δ_2 is smaller than partial responsibility level δ_1 because two factors contribute to underlending by the bank when $\lambda < \hat{\lambda}$, the undervaluation of the social value of the firm's rent and the non-refinancing of the firm if π_1 is realized in period 1, while only the first factor is present when $\lambda > \hat{\lambda}$.

5. MORAL HAZARD IN BANKING

We suppose now that the firm's profit is observable by the social regulator and the bank but that both face a moral hazard problem regarding the level of the firm's effort.

As for the insurer, he again observes neither profit nor effort. We characterize first the social optimum to be used as benchmark in this section, then the multiprincipal Nash equilibria and finally we derive the optimal responsibility policy.

5.1 *The Social Optimum under Moral Hazard.*

The proper benchmark for our analysis is now the optimum under moral hazard. For the same reasons as in the previous section, the profit of the bank and the expected social cost of an accident enter the social welfare function with a weight of $(1+\lambda)$ while the firm's utility enters with a weight of 1. Again, the optimal program will minimize the rent left to the firm because of the different weights in the social welfare function.

The firm will choose $e=1$ iff it finds interesting to incur the cost ψ_1, that is iff the wedge between its utility in the two states [accident or no accident] is large enough, that is iff:

$$(1-p_1)[\overline{\pi}-(\theta R^1+(1-\theta)R^2)]-\psi_1 \geq (1-p_0)[\overline{\pi}-(\theta R^1+(1-\theta)R^2)]-\psi_0$$

or iff

$$\theta R^1+(1-\theta)R^2 \leq \overline{\pi}-\frac{\psi_1-\psi_0}{p_0-p_1}. \tag{5.1}$$

The limited liability constraints of the firm are still given by (4.2) and its individual rationality constraint is now given by

$$\overline{\pi}-\theta R_1-(1-\theta)R_2+\left[(1-p_e)[\overline{\pi}-(\theta R^1+(1-\theta)R^2)]-\psi_e\right] \geq 0. \tag{5.2}$$

Distortions created by moral hazard will occur only when the combination of the limited liability constraints and the incentive compatibility constraint require to give up a (costly) rent to the firm. Incentive compatibility and $\lambda>0$ requires that (5.1) be binding and limited liability requires $\theta R_1+(1-\theta)R_2 \leq \overline{\pi}$. Therefore, if

$$\mathcal{R} \equiv -\psi_1+(1-p_1)\frac{\psi_1-\psi_0}{p_0-p_1},$$

is positive, that is if the cost of effort ψ_1 is large enough,[25] then the last term of (5.2) is positive for $e=1$; $\lambda>0$ then requires that $\theta R_1+(1-\theta)R_2=\overline{\pi}$ but nevertheless, the

[25] More precisely if $\psi_1 > [(1-p_1)/(1-p_0)]\psi_0$ which implies that $\mathcal{R}>0$.

positive rent $\mathcal{R}$ is given up to the firm. If $\mathcal{R} < 0$, that is if the cost of effort is sufficiently small, then the limited liability constraints are not binding[26] and it is possible to extract all the rent from the firm [(5.2) is then satisfied with an equality] and the first best can be achieved. In the following, we concentrate on the more interesting case where $\mathcal{R} > 0$. Under the social optimum contract, the bank's profit is therefore

$$\overline{\pi} + (1 - p_e)(\theta R^1 + (1 - \theta)R^2) - 2F \tag{5.3}$$

and the firm gets a rent equal to $\mathcal{R}$ iff $e = 1$.

Proposition 9: *The social optimum entails* $e = 1$ *iff*

$$(p_0 - p_1)d \geq \psi_1 - \psi_0 + \frac{\lambda}{1+\lambda}\mathcal{R} \tag{5.4}$$

and an investment rule defined as follows:

- *if* $e = 1$, *invest in both periods iff*

$$2\overline{\pi} - 2F - p_1 d - \psi_1 - \frac{\lambda}{1+\lambda}\mathcal{R} \geq 0 \tag{5.5}$$

- *if* $e = 0$, *invest in both periods iff*

$$2\overline{\pi} - 2F - p_0 d - \psi_0 \geq 0. \quad \| \tag{5.6}$$

Proposition 9 differs from the first best rule because of the need to give up an informational rent to the firm to induce it to choose $e = 1$. Both when making the investment decision and deciding on the optimal effort level, the social cost $\frac{\lambda}{1+\lambda}\mathcal{R}$ of this rent must be added to the other costs (noting however that a rent is needed only when $e = 1$ is induced). As the cost of public funds λ decreases, the cost of giving up a rent to the firm decreases also and the condition under which it is optimal to exert a high effort level converges to the condition under which it is optimal to do so under full information. As the cost of public funds λ increases, the cost of giving up rents to the firm increases also

[26] The wedge created in order to induce the firm to choose $e = 1$ is sufficient to cover the cost of the high level of effort.

and the condition under which it is optimal to exert a high effort level converges to that condition under which, as we will see below, it is in the interest of the bank to induce such an effort level when it is made fully liable for damages.

5.2 *The Multiprincipal Equilibria under Moral Hazard.*

The bank cannot observe the level of effort but perfectly observes profit. Hence, it can offer a financial contract which makes the level of payments dependent on the level of realized profit. If the financial contract offered is not effort inducing, then the bank captures all the profit net of ψ_0. If the bank decides to make the contract effort inducing, then it must give up a rent to the firm.

As for the position and role of the uninformed insurer, we are in a similar situation as in the previous sections. There will be no Nash equilibrium in which the firm will voluntarily buy an insurance contract. Therefore we can concentrate on equilibria with no insurance. From (5.1), (5.2) and (5.3), the bank's profit, when it induces $e = 1$ [a rent is then left to the firm and the individual rationality constraint (5.2) is not binding], is given by

$$\overline{\pi} + (1 - p_1)(\overline{\pi} - \frac{\psi_1 - \psi_0}{p_0 - p_1}) - 2F \tag{5.7}$$

and, when it induces $e = 0$ [no rent is then left to the firm and (5.1) does not hold but (5.2) is binding], is given by

$$\overline{\pi} - \psi_0 + (1 - p_0)\overline{\pi} - 2F.$$

Proposition 10: *The bank induces effort less often than called for by the second best optimal rule. When it induces $e = 1$, the bank lends less often than called for by the second best optimal investment rule iff*

$$p_1(d - \overline{\pi}) < \frac{\mathcal{R}}{1 + \lambda}.$$

When it induces $e = 0$, then it lends more often than called for, conditionally on $e = 0$, by the second best optimal investment rule. ‖

Proposition 10 balances two effects. On the one hand, the bank undervalues the cost of the externality since it values it at $p_1\overline{\pi}$ rather than at $p_1 d$; this leads the bank to lend too much and to induce effort less often than optimally. On the other hand, the bank values at $\mathcal{R}$ the cost of the rent left to the firm when socially it is valued at $\frac{\lambda}{1+\lambda}\mathcal{R}$; this leads the bank to lend too little and to induce effort less often than optimally. The two effects tend to reduce the effort level induced by the bank. But they have opposite impacts on the level of lending. When the bank induces $e = 0$, then only the first effect is present and therefore the bank lends too much. Is bank's liability the solution ?

5.3 *The Bank's Liability under Moral Hazard.*[27]

Consider the case where the social optimum requires the realization of a given project with $e = 1$. If, with no responsibility, the bank does not want to finance the project with $e = 1$, it is because the negative rent effect is greater than the positive externality effect. The optimal investment decision could only be obtained by subsidizing the bank if the investment is realized. Making the bank responsible would decrease its expected profit and certainly not induce it to finance the project.

A more interesting case is the following: suppose that when it is not liable for environmental damages, the bank is willing to finance the project with $e = 0$. Increasing the bank's responsibility could convince it to induce the appropriate choice of effort because of the greater loss it is now incurring if an accident occurs. However, it is clear that for levels of responsibility close to zero, the bank is not going to induce $e = 1$; for such a high level of effort to be induced, the level of responsibility of the bank must reach a certain threshold that we label δ_3 below. But at that level of responsibility, the bank is willing to finance the project iff its profit is non negative. Because the bank overvalues, in comparison with the social regulator, the cost of the firm's rent, it is possible for the bank's expected profit to be negative when the level of responsibility reaches δ_3 (in which case the project will not be financed by the bank) even if the project is socially valuable

[27] Compulsory insurance for the bank is very similar here to the bank's liability but may not induce effort from the firm for the same reason as in Proposition 2.

with $e = 1$.

Full responsibility leads to $e = 1$, that is to a decision of the bank to induce the firm to choose a high level of effort, iff

$$(p_0 - p_1)d > \psi_1 - \psi_0 + \mathcal{R}. \tag{5.8}$$

The bank will accept to lend iff $2\overline{\pi} - 2F - p_1 d - \psi_1 - \mathcal{R} \geq 0$ when $e = 1$ and iff $2\overline{\pi} - 2F - p_0 d - \psi_0 \geq 0$ when $e = 0$. Because of the rent effect, full responsibility is excessive from the point of view of investment since it kills the investment too often [under full responsibility, the bank induces $e = 1$ and lends iff $\mathcal{R} < \min\{(p_0 - p_1)d + (\psi_0 - \psi_1),\ 2\overline{\pi} - 2F - p_1 d - \psi_1\}$] while, from (5.8) and (5.4), it still leads to low effort too often.

Consider now partial responsibility. As before, let δd be the payment imposed by the law to the bank if an accident occurs. Then the *smallest* responsibility level δ which leads the bank to induce $e = 1$ is defined from (5.8) by

$$(p_0 - p_1)\delta d = \psi_1 - \psi_0 + \mathcal{R} \tag{5.9}$$

that is

$$\delta = \delta_3 = \frac{\psi_1 - \psi_0 + \mathcal{R}}{(p_0 - p_1)d}. \tag{5.10}$$

However, imposing responsibility level δ_3 is the correct policy only if it does not lead to the cancellation of the project, that is only if the bank's profit remains non negative. The cancellation of the project will happen despite the fact that the project with $e = 1$ is socially valuable if $2\overline{\pi} - 2F - p_1 \delta_3 d - \psi_1 - \mathcal{R} < 0$, that is if

$$(\frac{p_0}{p_0 - p_1} - \frac{\lambda}{1 + \lambda})\mathcal{R} > p_1(d - \frac{\psi_1 - \psi_0}{p_0 - p_1}) \tag{5.11}$$

which is clearly possible.[28] By looking for the optimal internalization of the externality, one runs the risk of killing the project by choosing too large a value of δ. The highest

[28] In particular, condition (5.11) holds if the social value of effort is low, that is if $(p_0 - p_1)d - (\psi_1 - \psi_0)$ is small [since $\frac{p_0}{p_0 - p_1} > 1 > \frac{\lambda}{1+\lambda}$].

responsibility level δ for which the bank will finance the project with $e = 1$ is

$$\delta = \delta_4 = \frac{2\overline{\pi} - \psi_1 - 2F - \mathcal{R}}{p_1 d}. \tag{5.12}$$

If $\delta_3 > \delta_4$, the project would not be financed by the bank. It is however possible that the project is socially valuable with $e = 0$. The highest responsibility level δ for which the bank will finance the project with $e = 0$ is

$$\delta = \delta_5 = \frac{2\overline{\pi} - \psi_0 - 2F}{p_0 d} \tag{5.13}$$

which is larger than 1 if the project is socially valuable with $e = 0$ and less than 1 otherwise. Summarizing, we have:

Proposition 11: *If $\delta_3 < \delta_4$, the second best is achieved [the project is realized with $e = 1$] by partial responsibility of the bank as defined by δ_3. If $\delta_3 > \delta_4$, partial responsibility of the bank cannot induce the appropriate effort level without killing the project. It is optimal to kill the project iff social welfare with $e = 0$ is negative (that is if $\delta_5 < 1$). Otherwise, a no responsibility policy is called for.* ‖

If $\delta_3 > \delta_4$, the project is socially valuable but the liability level necessary to induce $e = 1$ would kill the project. In that case, the second best could only be achieved with two instruments, for example with punitive liability combined with a subsidy if the investment is undertaken.

6. CONCLUSION AND IMPLICATIONS

We have derived separately the equilibrium and the (second best) optimum under complete information and when the bank (as well as the social regulator) suffers from moral hazard or adverse selection. Similar economic results would appear in the more general model with moral hazard and adverse selection simultaneously. Limited liability and risk neutrality imply that a firm, even if it is made liable for its environmental damage, will prefer to run the risk of bankruptcy rather than become insured even for a fair insurance premium. Moreover, it may choose to exert insufficient effort to decrease the probability of an environmental accident since it undervalues the social cost of an

accident. These factors lead to overlending by the bank. In the context of perfect monitoring of the firm by the bank, the bank's full liability for environmental damage when the firm is unable to pay the cleanup cost or indemnify the pollutees, provides the appropriate internalization of the externality and leads to optimal lending and safety effort behavior. Reaching the deep pocket of the bank solves the financial problem, but also leads to efficiency by suppressing the impact of the firm's limited liability.

However, banks suffer from various asymmetries of information with respect to the firms they finance. Agency costs are created which alter the behavior of the bank and the firm. The agency relationship obliges the bank to give up to the firm informational rents which the bank does not include in the benefits when performing a cost-benefit analysis for investment purpose and for effort purpose. Accordingly, the bank has an inclination to underinvest or to induce insufficient safety care. This *rent effect* opposes the *externality effect* for the investment decision and goes in the same direction as the externality effect for the safety care decision.

In view of the rent effect, full liability of the bank, to correct for the externality, is excessive for the investment decision and may be insufficient for the safety care decision. Imposing a high level of liability creates the risk of killing socially desirable projects. In general, liability of the bank is not a sufficient instrument to reach the second best allocation when rents must be given up either to induce effort or to induce the truthful revelation of profit levels.

Many of the assumptions were made to simplify the presentation and the analysis and could be relaxed without affecting the nature of the results; in particular, π_1 and π_2 could be made dependent, a discount rate could be introduced, effort could be a continuous variable as well as $p(e)$ and the firm might have been modeled as providing some amount of equity. All along the paper, the risk neutrality assumption has exacerbated the lack of interest of the firm to buy insurance. Risk aversion of the firm might create a voluntary demand for insurance but would not affect substantially the other economic conclusions. We have restricted the analysis to the case of a single bank and more generally of a single

creditor and since social efficiency requires that the rent captured by the firm be as small as possible, given that the cost of investment F and the payments made by the firm to the bank were assumed observable, we therefore gave the bank the power to extract as much rent as possible from the firm. The same analysis is valid also for a competitive banking context, in which polar cases would correspond to a zero profit condition on the banking sector, the usual competitive banking assumption, and to a lump sum tax on the banking sector. In the first case, the bank's profit is zero and the firm captures a larger rent, a situation which would increase the distortions as compared with the second best social optimum. In the second case, the government imposes a lump sum tax to the competitive banks equivalent to their expected profit level when the firm's rent is kept at its minimum level under limited liability and asymmetric information, a situation which corresponds to the case analyzed in this paper. All situations in between these two extreme ones can be analyzed using the same apparatus.[29]

Other extensions would be worthwhile to pursue. We have confined our analysis to the case where the risks involved were well defined risks raising no difficulties, beyond the moral hazard problem, in the writing of insurance contracts. In practice, relying on a compulsory insurance system might not be so straightforward in view of all the arguments which can be invoked to invalidate such insurance contracts; this raises issues of possible collusion between insurers and firms to escape a true internalization of externalities. In the context of pollution externalities, it would also be particularly interesting to pursue the analysis taking into account the difficulties of determining the probability distribution of severe environmental accidents. We must stress also the endogeneity of the information structures of the agents, in particular the banks. It would be interesting to take into account the way the allocation of responsibility affects the incentives of the banks to acquire information on the firms' activities. Finally, it is often the case that efforts to decrease costs or more generally to maximize profits affect negatively the effort devoted

[29] It would nevertheless be interesting to pursue the analysis in the case of multiple creditors to raise the issue of how to allocate responsibility among creditors. See Feess and Hege (1993) and Hyde, Rausser and Simon (1995) for such analyses.

to safety care[30] and it would be valuable to integrate this consideration.

Beyond these directions of theoretical research, we would like to summarize some preliminary practical implications we can derive from our analysis. Clearly, the responsibility system should be well defined ex ante in view of its interference with the banks' lending policy. The economic analysis leads us to distinguish two cases: either there are no serious agency costs for the bank or these costs are significant. In the first case, if the environmental risks are well defined, full responsibility of the bank is appropriate to ensure the internalization of the externality. If those costs are ill defined, then full responsibility remains appropriate if the cost for the bank of defining precisely the environmental risks is small enough. However, there are cases or industries where such information acquisition is likely to be very costly (there is also a free rider problem in defining those risks) and would precipitate the withdrawal of external (banking) financial resources from those industries. One could advise that the government either clarifies those risks or gives up making the banks responsible or at least fully responsible. We have shown in this paper that when agency costs are significant, partial responsibility should replace full responsibility. Partial responsibility balances the need to internalize the externality and the reluctance of banks to lend. Finally, in the case of risks which are not well defined, and therefore of an insurance market which cannot be relied upon and of possible excessive prudence of banks, it seems inevitable that ex ante authorization for carrying those risky activities should be obtained from the social regulator and that indemnification of the costs of an accident be covered by a governmental Superfund.

CERCLA and the related jurisprudence allocate responsibility according to the involvement of the bank into the management of the firm: full responsibility if the bank is involved and no responsibility otherwise. In view of our analysis, this would appear appropriate if the involvement in management was equivalent to the case of well defined risks and no (or small) agency costs, and no involvement was equivalent to ill defined risks with or without large agency costs. Clearly, there is no obvious equivalence be-

[30] See Laffont (1994).

tween these concepts and this might be one explanation of the level of controversy over CERCLA in the US and over similar legal attempts in other countries.

Appendix:
PROOFS OF THE PROPOSITIONS

Proof of proposition 1: Consider a candidate Nash equilibrium with $e = 0$ and an insurance contract with premium $p_0 d$ paid in period 1 without loss of generality. Given those values, the banking contract is such that $R_1 = \pi_1 - p_0 d - \psi_0$, $R_2 = \pi_2 - p_0 d - \psi_0$, $R^1 = \pi_1$ and $R^2 = \pi_2$ since complete information enables the bank to saturate the firm's individual rationality constraint. The firm's expected profit is therefore zero in a Nash equilibrium because it has zero profit if there is no accident, since the banking contract expropriates all its profit, and it has zero profit if an accident occurs, because of limited liability. If, given the above insurance and banking contracts, the firm deviates by not buying the insurance contract, its profit is $p_0 d$ [it saves the insurance premium] and therefore it will deviate and therefore voluntary insurance cannot be part of a Nash equilibrium. And similarly for a candidate Nash equilibrium with $e = 1$ and an insurance contract with total premium $p_1 d$ which could be paid over both periods. $\diamondsuit$

Proof of proposition 2: We are now in the case of compulsory insurance with the insurance sector observing only whether an accident occurred or not. Let $(s_1,\ s_2^0,\ s_2^1)$ be an insurance contract. The effort $e = 1$ will be induced if (3.2) is met. Because of the unobservability of profit in period 2, we must have $s_2^1 \leq \pi_1$ and $s_2^0 \leq \pi_1$. These constraints can be ensured with the smallest premium in period 1 if $s_2^1 = \pi_1$ and $s_2^0 = \pi_1 - (\psi_1 - \psi_0)/(p_0 - p_1)$ which can be positive or negative. Budget balance then requires $s_1 + p_1 s_2^1 + (1-p_1) s_2^0 = p_1 d$, that is $s_1 = p_1 d - p_1 \pi_1 - (1-p_1)[\pi_1 - (\psi_1 - \psi_0)/(p_0 - p_1)]$. Such a contract is feasible only if $s_1 \leq \pi_1$, hence condition (3.5) in the proposition [Note that if the insurance company was able to differentiate the premium in period 1 according to the level of profit in period 1, a weaker but similar condition would hold]. Consider now a potential Nash equilibrium with $e = 0$ and an insurance contract such that $s_1 + p_0 s_2^1 + (1 - p_0) s_2^0 = p_0 d$. Since $p_0 d < \pi_1$ by assumption, such a contract is feasible. Because of compulsory insurance, the banking contract will be indexed on the occurrence or not of an accident in period 2: $R_1 = \pi_1 - s_1 - \psi_e$, $R_2 = \pi_2 - s_1 - \psi_e$,

$R_0^1 = \pi_1 - s_2^0$, $R_1^1 = \pi_1 - s_2^1$, $R_0^2 = \pi_2 - s_2^0$, $R_1^2 = \pi_2 - s_2^1$. The bank lends if

$$\theta R_1 + (1-\theta)R_2 + \theta[p_e R_1^1 + (1-p_e)R_0^1] + (1-\theta)[p_e R_1^2 + (1-p_e)R_0^2] - 2F \geq 0,$$

that is if $2\overline{\pi} - p_e d - \psi_e \geq 2F$ and therefore, conditionally on the level of effort, it lends optimally. $\diamondsuit$

Proof of proposition 3: Because it is risk neutral and can benefit from the limited liability of the firm if there is an accident, the bank does not want the firm it controls to be insured. Indeed, for $e = 1$, the bank's profit is $2\overline{\pi} - p_1\overline{\pi} - \psi_1 - 2F$ with no insurance, and $2\overline{\pi} - p_1 d - \psi_1 - 2F$ with balanced insurance; hence the result, since $d > \overline{\pi}$. Consider then the case without insurance. The bank asks for $e = 1$ if

$$2\overline{\pi} - p_1\overline{\pi} - \psi_1 - 2F \geq 2\overline{\pi} - p_0\overline{\pi} - \psi_0 - 2F$$

that is if $\psi_1 - \psi_0 \leq (p_0 - p_1)\overline{\pi}$ instead of the first best rule $\psi_1 - \psi_0 \leq (p_0 - p_1)d$; hence the effort level $e = 1$ obtains less often than desired. Consider now the lending policy. If $\psi_1 - \psi_0 \leq (p_0 - p_1)\overline{\pi}$, then $e = 1$ and the bank lends if $\overline{\pi} + (1-p_1)\overline{\pi} - \psi_1 - 2F \geq 0$, that is if $2\overline{\pi} - p_1\overline{\pi} - \psi_1 - 2F \geq 0$ instead of the first best rule $2\overline{\pi} - p_1 d - \psi_1 - 2F \geq 0$. Therefore, the bank lends too often. If $\psi_1 - \psi_0 \geq (p_0 - p_1)\overline{\pi}$, then $e = 0$ and the bank lends if $2\overline{\pi} - p_0\overline{\pi} - \psi_0 - 2F \geq 0$; again, the bank lends too often. $\diamondsuit$

Proof of proposition 4: Direct from the text. $\diamondsuit$

Proof of proposition 5: Considering (4.5), we have

$$\frac{\partial W}{\partial \beta_2} = (1+\lambda)(\overline{\pi} - F)(1-\theta) > 0$$

which implies $\beta_2 = 1$; and

$$\begin{aligned}\frac{\partial W}{\partial \beta_1} &= (1+\lambda)\theta(\overline{\pi} - F) - \lambda(\overline{\pi} - \pi_1) \\ &= \theta(\overline{\pi} - F) - \lambda[(1-\theta)(\overline{\pi} - F) + (F - \pi_1)],\end{aligned}$$

a decreasing function of λ. Defining $\hat{\lambda}$ by

$$(1+\hat{\lambda})\theta(\overline{\pi} - F) = \hat{\lambda}(\overline{\pi} - \pi_1),$$

we obtain:
(i) If $\lambda \leq \hat{\lambda}$, $\partial W/\partial \beta_1 > 0$ implying $\beta_1 = 1$ [lending in the second period should occur if it occurs in the first period] and therefore $R_2 = R_1 = \pi_1$. Lending in the first period should occur iff the social welfare given by (4.5) is positive, that is iff

$$W(1,1) = (1+\lambda)[2\overline{\pi} - 2F - p_1 d - \psi_1] - \lambda[2(\overline{\pi} - \pi_1) - \psi_1] > 0,$$

[which holds iff (4.7) holds] where the first bracketed term is the unweighted total surplus when $\beta_1 = \beta_2 = 1$ and the second bracketed term is the rent left to the firm because of the limited liability constraint. The profit of the bank is given by

$$[2\overline{\pi} - 2F - p_1 d - \psi_1] - [2(\overline{\pi} - \pi_1) - \psi_1] < 0.$$

The social welfare function is decreasing in λ and ψ_1.
(ii) If $\lambda > \hat{\lambda}$, $\partial W/\partial \beta_1 < 0$ implying $\beta_1 = 0$ [lending in the second period should occur only if it occurs in the first period and the profit level π_2 is realized] and therefore $R_1 = \pi_1$ and $R_2 = \overline{\pi}$. Lending in the first period should occur iff the social welfare given by (4.5) is positive, that is iff

$$W(0,1) = (1+\lambda)[(2-\theta)(\overline{\pi} - F) - p_1 d - \psi_1] - \lambda[\overline{\pi} - \pi_1 - \psi_1] > 0,$$

[which holds iff (4.6) holds] where the first bracketed term is the unweighted total surplus when $\beta_1 = 0$ and $\beta_2 = 1$ and the second bracketed term is the rent left to the firm because of the limited liability constraints. The social welfare function is decreasing in ψ_1; but it decreases [increases] with λ if the profit of the bank, equal to $\pi_1 + (1-\theta)\overline{\pi} - (2-\theta)F - p_1 d$, is negative [positive]; contrary to case (i), that profit may be positive in the present case. $\diamondsuit$

Proof of proposition 6: Direct from the text. $\diamondsuit$

Proof of proposition 7: If $\lambda > \hat{\lambda}$, investment takes place in the social welfare program if (4.6) is satisfied, while investment takes place in the bank's program if (4.9) is satisfied, that is, using $\mathcal{R}(0,1) = \overline{\pi} - \pi_1 - \psi_1$, if

$$(2-\theta)(\overline{\pi} - F) - (1-\theta)p_1\pi_1 - \psi_1 - \mathcal{R}(0,1) > 0. \qquad (A.1)$$

Therefore investment occurs less often in the equilibrium than in the optimum if

$$p_1(d-(1-\theta)\pi_1) < \frac{1}{1+\lambda}\mathcal{R}(0,1).$$

If $\lambda < \hat{\lambda}$, investment takes place in the social welfare program if (4.7) is satisfied, while investment takes place in the bank's program if (4.9) is satisfied. Therefore investment occurs less often in the equilibrium than in the optimum if

$$p_1(d-(1-\theta)\pi_1) + (\mathcal{R}(1,1) - \mathcal{R}(0,1) < \theta(\overline{\pi}-F) + \frac{1}{1+\lambda}\mathcal{R}(1,1)$$

that is if

$$p_1(d-(1-\theta)\pi_1) < \frac{1}{1+\lambda}\mathcal{R}(0,1) + \left[\theta(\overline{\pi}-F) - \frac{\lambda}{1+\lambda}\big(\mathcal{R}(1,1)-\mathcal{R}(0,1)\big)\right]$$

which completes the proof. $\diamondsuit$

Proof of proposition 8: Full internalization of the externality is obtained by replacing $(1-\theta)p_1\pi_1$ in $(A.1)$ by $p_1 d$; it leads to the bank's decision rule: invest in period 1 if $2(\overline{\pi}-F) > \theta(\overline{\pi}-F) + p_1 d + \psi_1 + \mathcal{R}(0,1)$, which is independent of λ. When $\lambda > \hat{\lambda}$, the optimum calls for lending if $2(\overline{\pi}-F) > \theta(\overline{\pi}-F) + p_1 d + \psi_1 + \frac{\lambda}{1+\lambda}\mathcal{R}(1,1)$. Clearly, the banks invests less often than optimal. When $\lambda < \hat{\lambda}$, the optimum calls for lending if $2(\overline{\pi}-F) > p_1 d + \psi_1 + \frac{\lambda}{1+\lambda}\mathcal{R}(1,1)$. Therefore, the bank lends less often than optimal if

$$\theta(\overline{\pi}-F) + \mathcal{R}(0,1) - \frac{\lambda}{1+\lambda}\mathcal{R}(1,1) > 0. \qquad (A.2)$$

For $\lambda = \hat{\lambda}$, this expression can be rewritten as follows:

$$\begin{aligned}
&\theta(\overline{\pi}-F) + \mathcal{R}(0,1) - \frac{\lambda}{1+\lambda}\mathcal{R}(1,1) \\
&\qquad = \theta(\overline{\pi}-F) + \overline{\pi} - \pi_1 - \psi_1 - \frac{\theta(\overline{\pi}-F)}{\overline{\pi}-\pi_1}[2(\overline{\pi}-\pi_1)-\psi_1] \\
&\qquad = \overline{\pi} - \pi_1 - \psi_1 + \theta(\overline{\pi}-F)[\frac{\psi_1}{\overline{\pi}-\pi_1} - 1] \\
&\qquad = (\overline{\pi}-\pi_1-\psi_1) - \frac{\theta(\overline{\pi}-F)}{\overline{\pi}-\pi_1}(\overline{\pi}-\pi_1-\psi_1) \\
&\qquad = \frac{\hat{\lambda}}{1+\hat{\lambda}}(\overline{\pi}-\pi_1-\psi_1) > 0.
\end{aligned}$$

For λ smaller than $\hat{\lambda}$, the expression in $(A.2)$ is even larger. For $\lambda > \hat{\lambda}$, partial internalization leads to optimal first period lending if, comparing (4.6) and (4.9):

$$p_1(1-\delta)d = \frac{1}{1+\lambda}\mathcal{R}(0,1)$$

that is if

$$\delta = \delta_1 = 1 - \frac{\mathcal{R}_B}{(1+\lambda)p_1 d}.$$

For $\lambda < \hat{\lambda}$, partial internalization leads to optimal first period lending if, comparing (4.7) and (4.9):

$$p_1(1-\delta)d = \theta(\overline{\pi} - F) - \mathcal{R}(0,1) - \frac{\lambda}{1+\lambda}\mathcal{R}(1,1)$$

that is if

$$\delta = \delta_2 = 1 - \frac{\theta(\overline{\pi} - F) - \mathcal{R}(0,1) - \frac{\lambda}{(1+\lambda)}\mathcal{R}(1,1)}{p_1 d}$$

which can be written (4.13). $\diamondsuit$

Proof of proposition 9: Let us first derive the social welfare when $e = 1$ is induced. We must solve the following program

$$\text{Max } (1+\lambda)[\theta R_1 + (1-\theta)R_2 + (1-p_1)(\theta R^1 + (1-\theta)R^2) - 2F] + (1+\lambda)p_1(\overline{\pi} - d)$$

$$+ [(\overline{\pi} - \theta R_1 - (1-\theta)R_2 - \psi_1) + (1-p_1)(\overline{\pi} - \theta R^1 - (1-\theta)R^2)]$$

s.t.

$$\theta R^1 + (1-\theta)R^2 \leq \overline{\pi} - \frac{\psi_1 - \psi_0}{p_0 - p_1}$$

$$\overline{\pi} - \theta R_1 - (1-\theta)R_2 - \psi_1 + (1-p_1)(\overline{\pi} - \theta R^1 - (1-\theta)R^2) \geq 0$$

For $\lambda > 0$ and $-\psi_1 + (1-p_1)\frac{\psi_1 - \psi_0}{p_0 - p_1} > 0$, the solution entails $\theta R_1 + (1-\theta)R_2 = \overline{\pi}$. Accordingly, the social welfare is

$$(1+\lambda)[\overline{\pi} - 2F + (1-p_1)(\overline{\pi} - \frac{\psi_1 - \psi_0}{p_0 - p_1}) + p_1\overline{\pi} - p_1 d] + [(1-p_1)\frac{\psi_1 - \psi_0}{p_0 - p_1} - \psi_1]. \quad (A.3)$$

Investment must take place if

$$2\overline{\pi} \geq 2F + \psi_1 + p_1 d + \frac{\lambda}{1+\lambda}\mathcal{R}$$

where $\mathcal{R}$ is the rent captured by the firm.
If $e = 0$, the social welfare is

$$(1 + \lambda)(2\overline{\pi} - 2F - \psi_0 - p_0 d) \tag{A.4}$$

and investment must take place if $2\overline{\pi} \geq 2F + \psi_0 + p_0 d$.
And finally, comparing $(A.3)$ and $(A.4)$, $e = 1$ must be induced if

$$(p_0 - p_1)d \geq \psi_1 - \psi_0 + \frac{\lambda}{1 + \lambda}\mathcal{R}$$

which completes the proof. $\diamondsuit$

Proof of proposition 10: If the bank induces $e = 1$, its expected profit is given by (5.7) which is equal to

$$2\overline{\pi} - (1 - p_1)\frac{\psi_1 - \psi_0}{p_0 - p_1} - p_1\overline{\pi} - 2F.$$

Hence it will lend if

$$2\overline{\pi} \geq 2F + p_1\overline{\pi} + \psi_1 + \mathcal{R}$$

which, compared to the second best optimal investment rule (5.5), leads to the result that the bank lends less often than called for by the second best optimal rule if

$$p_1(d - \overline{\pi}) < \frac{\mathcal{R}}{1 + \lambda}.$$

If $e = 0$, the expected profit of the bank is $\overline{\pi} - \psi_0 + (1 - p_0)\overline{\pi} - 2F$. So the bank induces $e = 1$ iff

$$(p_0 - p_1)\overline{\pi} > \psi_1 - \psi_0 + \mathcal{R}$$

which, compared to the second best optimal condition (5.4), generates the result that the bank induces effort less often. When the bank induces $e = 0$, it lends whenever its profit $2\overline{\pi} - 2F - p_0\overline{\pi} - \psi_0$ is positive which, when compared to the optimal decision rule (5.6), generates the result that the bank lends more often than called for, conditionally on $e = 0$, by the second best optimal rule. $\diamondsuit$

Proof of proposition 11: Direct from the text. $\diamondsuit$

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