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# Financial Assurance versus Liability as Solutions to the Judgment-Proof Problem

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## Abstract

A firm is said to be judgment-proof if it can cause an accident and then skirt its environmental liabilities by pleading bankruptcy. Judgment-proofness is a public-policy problem because it saddles society with uncompensated liability and stifles the firm's incentive to undertake due care. We employ a simple lending model that incorporates moral hazard to compare three instruments designed to remedy the judgment-proof problem; namely, environmental bonds, mandatory liability insurance and liability. Incentives are unambiguously stronger under liability than they are under either bonds or mandatory insurance. Credit is more rationed and the span of potentially damaging projects is lower under bonds and mandatory insurance than they are under liability. The relative impact of these instruments on social welfare ambiguously depends on entrepreneurial wealth.

**JEL Classifications**: K13, K32, D82, Q58

**Keywords**: financial assurance, extended liability, liability, judgment-proof problem

## 1. Introduction

It is not uncommon for a firm to be forced into bankruptcy because its environmental liabilities greatly exceed its asset base. Such a firm is said to be judgment-proof (Shavell, 1986). Judgment-proofness is a problem because, in the absence of any interventions, it burdens society with uncompensated liability and stifles the firm's incentive to exercise adequate care *ex ante*.



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The available policy instruments to remedy the judgment-proof problem include financial assurance and extended liability [1]. Financial assurance schemes require potential polluters to demonstrate--prior to engaging in potentially damaging activities—financial resources adequate to indemnify environmental damage that may arise in the future[2]. These schemes may be regarded as *ex ante* policies since they are activated prior to an accident. Under the doctrine of extended liability (hereafter, liability), by contrast, courts impose liability on the lender who financed the environmentally risky project. In essence, victims of environmental accidents use the deep pockets of lenders to obtain redress when the primary producer of the injury is bankrupt. Liability rules can thus be regarded as *ex post* policies in the sense that they are designed to deal with an environmental externality only after it has been generated (Boyer & Laffont, 1997; Boyd & Ingberman, 1997).

A small literature has emerged to examine the implication of these instruments, most notably, Lewis and Sappignton (2001), Boyer and Laffont (1997), Farber (1991), Shavell (2005), Mathis and Baker (2002), Gerard and Wilson (2009), Ferreira, Suslick, Farley, Costanza, and Krivov (2004), Boyd and Ingberman (1997), Boyd (2002), Dionne and Spaeter (2003), Pitchford (1995), Feess and Hege (2003), Hutchinson and van't Veld (2005), Dana and Wiseman (2014) and van't Veld and Shogren (2012). With the exception of van't Veld and Shogren (2012), Dana and Wiseman (2014), Farber (1991) and Shavell (2005), all the studies cited above share a common feature in that they examine one or the other instrument. That is to say, they make no attempt to determine the relative impact of financial assurance instruments (*ex ante* tools) versus liability rules (*ex post* tools), despite the existence of well-established theoretical arguments emphasizing each set of instruments. While the three studies by van't Veld and Shogren (2012), Farber (1991) and Shavell (2005) do compare the instruments, they neglect to consider the financial decision problems of the firm. More precisely, in all the three studies, the firm is presumed to own its capital outright and thus its decisions or actions do not fall prey to financing constraint. The work by Dana and Wiseman (2014) evaluates the instruments, but does so in a framework that is largely descriptive, devoid of any rigorous theoretical analysis.

This paper attempts to address these shortcomings in three ways. First, we explicitly compare *ex ante* policies to *ex post* schemes in the same framework. Second, we take cognizance of the fact that the polluting firm is financially constrained. Third, we link regulatory compliance with the firm's financial constraint. In our framework, the firm lacks adequate internal resources to both undertake its initial investment and also demonstrate compliance, and must therefore borrow from capital markets. That is, compliance with regulation may entail an outlay of capital and hence exacerbate the firm's financial constraint. Thus, our model provides a synthesis of environmental policy, firm's financing decision problem and environmental outcomes.

The model we employ is of the simple. Liquidity-constrained firms must secure external resources to finance projects that have the potential to cause a damaging environmental accident. A firm can reduce the probability of an accident by exercising care or safety precaution. Each firm is characterized by the size of its initial wealth endowment. Thus, our model assumes that firms are

[1] These rules have been enshrined in several pieces of legislation. Examples include the EU Environmental Liability Directive (ELD) and US Resource Conservation and Recovery Act (RCRA). ELD requires member states to take measures to encourage the development of financial security instruments and markets by the appropriate economic and financial operators. . . with the aim of enabling operators to use financial guarantees to cover their responsibilities under the Directive. Under RCRA, owners and operators of facilities that treat, store, and dispose of hazardous chemicals must demonstrate financial responsibility for third-party damages.

[2] One argument in favour of financial assurance rules is simple and sound: because the costs of accidents are internalized and polluters have the financial means to pay victims, both efficient deterrence and just compensation result from private decisions (Katzman, 1988; Shavell, 2005; Feess & Hege, 2002, 2003).

heterogeneous. There is a moral hazard problem on the part of the firm because the level of care is not observable and cannot therefore be directly contracted upon *ex ante*. An accident causes a large-scale environment damage and bankrupts the firm (i.e., the firm is judgment-proof).

We evaluate two financial assurance schemes—environmental bonds and mandatory liability insurance—versus liability, in terms of their relative impacts on (a) incentives, (b) the extent of credit rationing and (c) welfare. With regard to the first two criteria, the ranking of the instruments is unequivocal: the bonding mechanism performs the worst with respect to credit rationing and the optimal level of care; liability yields the best outcome; mandatory insurance is somewhere in between. The logic behind these results is as follows. Under environmental bonding the firm needs greater outside financing. It thus borrows more and repays a correspondingly higher amount to its lender compared to the other mechanisms. This implies that the entrepreneur appropriates a relatively smaller amount of the residual surplus in the states of the world in which the firm is solvent. In contrast, liability rule imposes no such additional financing burden on the entrepreneur. By allocating responsibility for the environmental harm to the lender, liability relieves the firm from the shackles of regulation so the firm is less financially constrained under liability rule than it is under environmental bonding. Mandatory insurance parallels environmental bonding in that it requires the entrepreneur to borrow to finance both its initial investment and demonstrate compliance. However, it differs from environmental bonding in that it imposes a less onerous borrowing and repayment burden. More precisely, under mandatory insurance, the entrepreneur need not finance the entire liability amount. Rather, because liability insurance is purchased at an actuarially fair amount, the additional financial burden that regulation engenders is equivalent to the expected liability. In sum, among the three mechanisms, the firm is most constrained and the entrepreneurial moral hazard is most severe under environmental bonding; the firm is least constrained and the entrepreneurial moral hazard is least severe under liability rule.

As for social welfare, the ranking of the instruments is surprisingly ambiguous. There are two reasons for this: (a) The moral hazard problem is resolved at different levels of wealth, depending on the instrument in place. In particular, the moral hazard problem is resolved at a lower level of wealth under liability than it is under the bonding mechanism precisely because the firm is less financially constrained under the former mechanism; it is resolved at an intermediate level of wealth under mandatory insurance. (b) At a sufficiently high level of wealth, the optimal contract actually induces the firm to overprotect, relative to the social optimum. Thus, in our model, some potential injurers overprotect, others undertake the socially optimal level of care, and yet others underprotect. Together, (a) and (b) yield a non-monotonic, inverted U-shaped relation between social welfare and entrepreneurial wealth for each instrument. More importantly, the social welfare functions intersect with the result that the relative performance of the schemes, when evaluated solely on the basis of social welfare, critically depends on the level of entrepreneurial wealth. In particular, at lower levels of wealth, liability yields the best social outcome; at higher levels of wealth, environmental bonding delivers the highest level of social welfare; mandatory insurance outperforms the other two mechanisms when wealth is in the intermediate range.

The foregoing result has a particularly striking implication for instrument choice. It suggests that a regulatory regime that is awake to firm idiosyncrasies cannot rely exclusively on single instrument to remedy the judgment-proof problem. Instead, it might involve the regulator, first, "segmenting" entrepreneurs according to their levels of wealth and then prescribing a distinct instrument for each segment of the entrepreneurial class as follows: (a) liability rule for entrepreneurs with low wealth, (b) assurance bonds for entrepreneurs with high wealth and (c) insurance for firms with intermediate amounts of wealth.

Boyd and Ingberman (1997), Boyd (2002), Dionne and Spaeter (2003), Pitchford (1995), Feess and Hege (2003), Boyer and Laffont (1997) and Hutchinson and van't Veld (2005) focus exclusively on extended liability. They find that the degree to which this instrument can restore a firm's incentive to exercise care depends on whether the firm's actions can be observed. By contrast, Mathis and Baker (2002), Gerard and Wilson (2009) and Ferreira *et al*., (2004) examine the implication of assurance bonds. This article is complimentary in that it shows how the safety measures undertaken by the firm vary according to the type of instrument used by the regulator. This element is naturally absent from these papers.

As in this paper, the three studies by Shavell (2005), Farber (1991) and van't Veld and Shogren (2012) evaluate the alternative instruments. In Shavell (2005), two financial assurance instruments; namely, insurance requirements and minimum asset requirements, which closely approximate environmental bonds, are compared. He finds that the relative impact of these instruments on incentives depends importantly on the information structure. In the absence of moral hazard, insurance tends to improve incentives to reduce risk relative to asset requirements. However, when insurers cannot observe levels of care, the dilution of incentives is more pronounced under compulsory liability insurance than under asset requirements. Unlike Shavell (2005), however, here we consider a framework where the injurer is financially constrained and the credit market plays a role.

Farber compares precisely the same set of instrument that we evaluate in this paper and fails to unambiguously rank them. This ambiguity stems from a host of factors, including the divergence between social and private discount rates, degree of risk aversion, and refund policy. van't Veld and Shogren (2012) show that whereas strict liability yields too little care, relative the social optimum, combining strict liability with some form of bonding may achieve the social optimum. Both Farber (1991) and van't Veld and Shogren (2012) differ from our model in one important respect: they abstract away from informational or agency problems, implicitly assuming instead that there is full information.

The rest of this paper is arranged as follows. Section 2 develops the central elements of the model. Section 3 characterizes the solution to the borrower's problem under financial assurance schemes. Section 4 derives the corresponding solution under liability. Section 4 evaluates the relative impact of the instruments. Section 5 discusses the results. Section 6 concludes. The proofs that are not in the text are provided in the Appendix.

## 2. The Model

There are four key players in the model: An environmental regulator, a continuum of mass one of entrepreneurs, lenders (or banks) and a victim. For simplicity, we assume that all parties are risk neutral. Each entrepreneur can launch a project, but lacks adequate resources to do so.[3] There are two important dates in the model: date 0 and date 1. No one discounts. At date 0, an entrepreneur may start a project. Each project requires a fixed initial investment of $I$. At date 1, each started project realizes a costlessly verifiable net cash flow $v$ from which all financing payments and environmental claims are drawn. Also, at this date, there is a chance that the project will cause an environmental accident and inflict harm on the victim. We express the harm in monetary terms and denote it by $h$. We assume that $h>v$. We can think of the accident in question as a large scale environmental disaster that drives the firm into bankruptcy.

The probability of an accident is denoted by $(1-e)$, where $e \in [0, 1]$ is the level of care or safety precaution exercised by the entrepreneur. Thus the probability $(1- e)$ is determined by the entrepreneur through the expenditure of care or precaution. Denote by $\wp(e)$ the nonpecuniary disutility of care required to avoid an accident with probability $e$. We take $\wp(e)$ to be quadratic

[3] Throughout we use entrepreneur, firm, borrower and injurer interchangeably.

$$\wp(e) = e^2/2B,$$

where $B$ is a parameter greater than zero.

Each entrepreneur is endowed with her initial wealth $A$. Entrepreneurs differ with regard to $A$, but are otherwise identical.[4] Denote by $F(A)$ the cumulative distribution function, which is assumed to be twice continuously differentiable and denote by $f(A)$ the corresponding density function defined over the interval $\Lambda \equiv [0, \bar{A}]$. $F(A)$ indicates the proportion of entrepreneurs with liquid wealth less that $A$. We assume that $A<I$ so entrepreneurs must finance any investment shortfall from lenders. Lenders operate in a competitive capital market and can raise an unlimited supply of capital at an exogenously given riskless rate of interest $\rho$.

While the functional form of $\wp(.)$ is common knowledge, only the entrepreneur observes the magnitude of care ($e$) expended. Thus, the level of care $e$ is not contractible. This implies that the relationship between entrepreneurs and lenders is subject to a moral hazard problem. Thus, in order for the entrepreneurs to exercise adequate care, they must be either closely monitored or be given proper incentives.

When an accident occurs and the borrower defaults, bankruptcy procedures are initiated and the project (or firm) is liquidated. We assume that the firm's liquidation value is $W<v$.

A loan contract between an entrepreneur with wealth $A$ and its lender specifies a repayment schedule $T(A)$ such that:

$$T(A) = \begin{cases} RD(A) & \text{if the project causes no accident} \\ W & \text{if the project causes an accident,} \end{cases}$$

where $D(A)$ is the loan size, which depends on the entrepreneur's wealth and $R$ is the quoted loan factor (i.e. one plus the quoted interest rate on loans). Thus the lender is presumed to enjoy a "senior claim" on the firm's cash flow. This means that in bankruptcy, the lender forecloses on the firm's realizable assets $W$ so the entrepreneur and the victim get nothing from the firm.

## 2.1. Benchmark Solution

As a useful benchmark, first consider the case where there is no moral hazard problem, care is observable and a benevolent social planner can decide how much precaution each firm should undertake. A project operated by a borrower with wealth level $A$ generates cash flows $v$ to be shared between the borrower and the investor in the event that there is no accident and has a liquidation value of $W$ in the event of an accident. The opportunity cost of external funds to finance this project is $(1+\rho)I$, while the victim suffers damage $h$ with probability (1-$e$). It follows that the net surplus created by project $A$ is

$$n(A) = ev + (1-e)W - (1-e)h - (1+\rho)I - \wp(e) \tag{1}$$

The socially optimal amount of care for the potential injurer can be obtained by maximizing the expected social surplus generated by all entrepreneurs:

$$max_e \ S = \int_{\Lambda} n(A)f(A)dA \tag{2}$$

[4] An alternative assumption would be to assume that entrepreneurs differ in terms of the magnitude of their environmental harm. From a qualitative point of view, the results obtained would be very much the same.

Solving this problem is immediate. At the unique level of $e$ that maximizes (2), $e^*$, the marginal cost of precaution equals to the marginal expected benefit of precaution; that is,

$$v - W + h - \wp'(e^*) = 0 \tag{3}$$

As can be seen, the optimal level of care is independent of entrepreneurial wealth. Apparently, only the total mass of entrepreneurs, not their identity is relevant. Throughout, we refer to the benchmark level of care $e^*$ as the first-best level. We will say that a firm "overprotects" when its level of care is greater than $e^*$ and "underprotects" when its level of care is less than $e^*$.

Substituting for $e$ in equation (1) using equation (3) gives the optimal net surplus created by a project operated by an entrepreneur with wealth A:

$$n^* = \wp(e^*) + W - h - (1 + \rho)I. \tag{4}$$

The optimal level of social welfare in this benchmark case is thus given by

$$S^* = \int_0^{\bar{A}} n^* f(A) dA = n^* \tag{5}$$

Since $n^*$ does not depend on $A$, it follows that, in this first-best world, the level of welfare does not depend on entrepreneurial characteristics, that is, on $A$. Assuming that $n^* \geq 0$, it is therefore socially optimal to undertake all projects regardless of the entrepreneurial characteristics.

With these preliminaries out of the way, we now proceed to consider the solution to the borrower's problem under two alternative policy instruments: In the first case, we introduce and examine two financial assurance schemes; namely, environmental bonds and mandatory insurance. In the second setting, we examine liability.

## 3. Financial Assurance

Financial assurance rules require potential injurers to demonstrate—*ex ante*—the financial resources necessary to compensate for environmental damage that may arise in the future. The arguments for these rules have been laid out by Boyd (2002). The most appealing, perhaps, is the idea that these rules may induce firms to internalize perceived social costs into their private resource allocation decisions. Several financial assurance mechanisms exist. These include insurance, bonds, corporate parent guarantees, or financial tests. The first three mechanisms require that the firm to provide tangible guarantee that funds will be available when needed. Financial tests, by contrast, only require the firm to provide financial statements demonstrating viability should it face an environmental claim.

In this paper, we focus on only two assurance schemes, namely, environmental bonds and mandatory liability insurance. These schemes are by no means novel, neither is their application restricted to environmental problems. Mandatory liability insurance is akin to mandatory automobile insurance and minimum capital requirements for banks: they share a common purpose of expanding the recovery of damages for the victims and the deterrence of inappropriate risk-taking (OECD, 2003). Construction bonds parallel environmental bonds in that they both provide a legal guarantee of indemnity by a solvent third party in case of a performance failure.

### 3.1. Environmental Bonding (EB)

Consider a simple bonding mechanism where the regulator prescribes the bond amount $l \leq h$ and then mandates the firm to fund an escrow account in the amount $l$ prior to undertaking its project.[5] For simplicity and without loss of generality, the interest on the escrow account is normalized to zero. The escrow agreement gives the regulator full control over the account until the bond is released. If the firm does not cause an accident, the bond is released and the deposited amount is refunded. In the event of an accident, however, the funds in the escrow are used by the regulator to indemnify the environmental harm suffered by the victim. Faced with this incentive structure, the firm will have the incentive to internalize its impacts on social welfare in order to ensure recovery of their bond (see, for example, Shogren, Herriges, & Govindasamy, 1993).

An entrepreneur with $A$ must allocate an amount $I$ for initial investment and place $l$ in an escrow account out of her wealth $A$. Her borrowing requirement, $D_b(A)$, is thus given by equation (6):

$$D_b(A) = I + l - A. \tag{6}$$

The lender's expected payoff is given by

$$\pi(A; e, R) = eRD_b(A) - (1+\rho)D_b(A) + (1-e)W \tag{7}$$

Equation (7) says that with probability $e$ there is no accident, in which case the firm is solvent and the lender is repaid $RD_b(A)$. With probability $(1-e)$, however, a damaging accident occurs. In the event, the firm goes into bankruptcy and the lender recoups the firm's liquidation value $W$. Equation (7) also says that, whether or not the firm is solvent, the lender foregoes $(1+\rho)D_b(A)$ that it would have earned on an alternative investment.

The expected payoff for a borrower with wealth $A$ is given by

$$u(A; e, R) = e[v - RD_b(A)] - (1-e)l - \wp(e). \tag{8}$$

Equation (8) says that with probability $e$ there is no accident, in which case the firm is solvent and appropriates the residual $v - RD_b(A)$. With probability $(1-e)$, however, a damaging accident occurs. In this case, the firm goes into bankruptcy and forfeits the bond in its entirety. Equation (8) also says that, whether or not the firm is solvent, the firm incurs disutility from exercising care.

The program of the borrower in this setting, stated as *EB*, can be written as

$$\max_{\{e,\, R\}} u(A; e, R) \tag{9}$$

subject to, for all $\Lambda \equiv [0, \bar{A}]$

$$\pi(A; e, \mathrm{R}) \geq 0 \tag{10}$$

$$e \in arg \max_{e'} u(A; \mathrm{e}, \mathrm{R}) \tag{11}$$

[5] This is an example of a cash bond. The alternative is a surety bond. In its basic form, a surety bond requires the firm to obtain a corporate surety bond which must cover any potential environmental damage.

Inequality (10) is the lender's participation constraint. It requires that the lender earn at least its alternative opportunity payoff, which is normalized to zero. Equation (11) is the borrower's incentive compatibility condition. It says that the firm's level of care should be optimal given contract *T(A)*. Proposition 1 characterizes the solution to the borrower's problem. The proof is relegated to the Appendix.

**Proposition 1**. *The solution to the borrower's problem under mechanism EB is as follows:*

*(i) The set of borrowers and the optimal loan price are, respectively, S = $[A_b, \bar{A}]$ and $R_b(A)$, where*

$$A_b = I + l - \frac{W}{(1+\rho)} - \frac{B(v - W + l)^2}{4(1+\rho)}, \tag{12}$$

*and*

$$R_b(A) = \frac{(1+\rho)}{e_b(A)} - \frac{\big(1 - e_b(A)\big)W}{e_b(A)(v - W + l)}. \tag{13}$$

*(ii)The optimal level of care is given by*

$$e_b(A) = \frac{B}{2}\left\{(v - W + l) + \left[\frac{4}{B}(A - A_b)\right]^{1/2}\right\} \tag{14}$$

An important property of the solution to the borrower's problem is that outside financing is feasible only for entrepreneurs who are sufficiently wealthy. This stands in sharp contrast to the first-best outcome where all borrowers, regardless of their wealth, are able to undertake their projects. Under limited information, poor entrepreneurs essentially disqualify themselves from the credit market. The reason for this is that in order to finance their investment, this calibre of entrepreneurs would need to borrow substantially. The resulting huge repayment burden would leave with an insignificant share of the marginal return from care and thus destroy all incentives to provide care.

Equation (13) records the optimal interest rate. Equation (15) shows that the optimal rate of interest is increasing.

$$R_b^{\prime(A)} = \frac{e_b'(A)\{R_b D_b(A) - W - [e_b(A) - (1+\rho)]\}}{e_b(A)(v - W + l)} < 0. \tag{15}$$

Note that $R_b^{\prime(A)} < 0$ since $RD_b(A)$-$W$>0, by assumption, $[e_b(A) - (1+\rho)]$<0, from the binding participation constraint, and $e_b'(A) > 0$, by equation (16). This result follows from the fact that the level of care is a monotonically increasing function of *A* (see equation 16). More precisely, as *A* increases, the probability that the firm will avoid an accident and remain solvent also increases. This in turn implies that wealthier entrepreneurs must face a lower interest.

The optimal level of care is characterized by (14), which shows that the level of care increases in *A*:

$$e_b'(A) = \left[\frac{4}{B}(A - A_b)\right]^{-1/2} > 0 \tag{16}$$

Thus, entrepreneurial wealth, by reducing the optimal rate of interest, reduces the severity of the moral hazard problem. The following Proposition reveals an interesting relationship between the incentive to undertake care and entrepreneurial wealth when the level of mandated coverage is set equal to the amount of harm.

**Proposition 2** *Suppose that the bond amount is set equal to the amount of harm (i.e., l=h). Then there exists a critical wealth level* $A_b^*$>$A_b$ *such that*:

$$e_b(A)\begin{cases} < e^* \ if & A < A_b^* \\ = e^* \ if & A = A_b^* \\ > e^* \ if & A > A_b^* \end{cases} \tag{17}$$

*Proof.*

Imposing the condition *l=h*, we can rewrite equation (3) as

$$\frac{1}{2}\left\{(v - W + l) + [(v - W + h)^2]^{1/2}\right\} = \wp'(e^*) \tag{18}$$

and equation (14) as

$$\frac{1}{2}\left\{(v - W + l) + [(v - W + h) - \varphi_b(A)]^{1/2}\right\} = \wp'\big(e_b(A)\big), \tag{19}$$

where

$$\varphi_b(A) = \frac{4}{B}[(1+\rho)(I + h - A) - W] \tag{20}$$

is the distortion term. Comparing (18) and (19), it is straightforward that $e_b(A) > e^*$ if $\varphi_b(A) < 0$, $e_b(A) < e^*$ if $\varphi_b(A) > 0$, and $e_b(A) = e^*$ if $\ni_b(A) = 0$. Define $A_b^*$ such that $\varphi_b(A_b^*) = 0$. Evidently,

$$A_b^* = I + h - \frac{W}{(1+\rho)}. \tag{21}$$

Condition (17) now follows. Q.E.D.

Entrepreneurial wealth lessens the severity of the moral hazard problem by reducing the entrepreneur’s repayment burden and increasing the marginal reward for care. Proposition 2 simply makes the point that at a sufficiently high level of wealth, the amount borrowed and the repayment burden become so insignificant as to essentially make the borrower the residual claimant of all returns from care. However, too much wealth results in overprotection, in much the same way that too little wealth, by making the marginal reward for care too small, induces underprotection.

### 3.2. Mandatory Insurance (MI)

Suppose now that, in order to undertake a project, the entrepreneur must demonstrate to the regulator that it has enough liability insurance to indemnify future environmental damage. As in the previous section, we denote by *l≤h* the amount of insurance coverage mandated by the regulator.

Taking the amount of coverage as given, the entrepreneur writes two sets of contracts. First, there is a loan contract, which, as previously noted, stipulates the repayment schedule *T(A)*. Second, there is an insurance contract specifying the amount of premium *pl*, where $p \in (0, 1)$. We assume that the entrepreneur simultaneously offers the two sets of contracts to the lender. One justification for this assumption is that the lender cross-sells insurance products so the lender and the insurer are in actuality one and the same entity. This assumption is broadly consistent with the observation that financial institutions have increasingly become multi-service institutions. In a number of jurisdictions, legislative changes and other innovations have over the years allowed financial institutions to expand their services beyond their traditional core functions of financial intermediation. For example, the US Gramm-Leach-Bliley Act (GLBA), which was enacted in 1999, now permits single holding companies to offer banking, securities, and insurance.[6] In Canada, changes to the Bank Act have blurred the distinction between financial institutions and the services they offer.

Thus, in our model, the entrepreneur essentially offers the lender a 'grand' contract that contains both financing and insurance elements. We take it that insurance services are offered in a competitive market. With no underwriting costs, the expected payoff from an insurance contract is given by

$$m(A; p, e) = pl - (1 - e)l \tag{22}$$

The firm must finance both its initial investment $I$ and the purchase of insurance at cost $pl$. Its investment shortfall, which also is its borrowing requirement, is thus given by

$$D_m(A) = I + pl - A \tag{23}$$

Comparing equation (23) to equation (6), we see that the firm is compelled to take on more leverage under a bonding mechanism than under mandatory insurance; that is, the firm is more financially constrained when it must post a bond than when it must purchase an insurance coverage from the market place. The borrower's expected payoff is given by

$$u_s(A; e, R, p) = e[v - RD_s(A)] - \wp(e). \tag{24}$$

The lender's expected payoff is given by

$$\pi_s(A; e, R, p) = eRD_s(A) - (1 + \rho)D_s(A) + (1 - e)W \tag{25}$$

The program of the borrower in this setting, stated as *MI*, can be written as

$$\max_{\{e,\, R, p\}} u_s(A; e, R, p) \tag{26}$$

subject to, for all $\Lambda \equiv [0, \bar{A}]$,

$$\pi_s(A; e,\ \mathrm{R}, \mathrm{p}) \geq 0 \tag{27}$$

[6] This Act essentially repealed the parts of the Bank Holding Company Act of 1956 that separated commercial banking from the insurance business.

$$e \in arg \max_{e'} u_s(A; \text{e, R, p}) \tag{28}$$

$$m(A;\, p, e) = pl - (1-e)l \geq 0 \tag{29}$$

Problem *MI* and problem *EB* differ in two respects: First, as noted above, the firm is more constrained under *EB* than it is under *MI*. Second, problem *MI* has the additional constraint given by equation (29), which ensures that the lender (or the insurance company) will at least break even on the insurance contract.

The key features of the solution to problem SB are now reported in the following Proposition. The proof and interpretation are analogous to those of Proposition 1, and are therefore omitted.

**Proposition 3** *The solution to the borrower's problem under mandatory insurance is characterized as follows:*

*(i) The set of borrowers and the optimal loan price are, respectively,* $S_s = [A_s, \bar{A}]$ *and* $R_s(A)$*, where*

$$A_s = I + l + \frac{W}{(1+\rho)} - \frac{B(v - W + (1+\rho)l)^2}{4(1+\rho)}, \tag{30}$$

*and*

$$R_s(A) = \frac{(1+\rho)}{e_s(A)} - \frac{\big(1 - e_s(A)\big)W}{e_s(A)\big(I + \big(1 - e_s(A)\big)l - A\big)}. \tag{31}$$

*(ii)The optimal level of care is given by*

$$e_s(A) = \frac{B}{2}\left\{(v - W + (1+\rho)l) + \left[\frac{4}{B}(A - A_s)\right]^{1/2}\right\} \tag{32}$$

Of immediate interest is how the two assurance options compare. Proposition 4 shows that the two financial assurance schemes have markedly different outcomes.

**Proposition 4** *(i) The critical values* $A_b$ *and* $A_s$ *below which borrowing is not feasible satisfy* $A_b > A_s$*. (ii) In the region where financing is feasible under the two options,* $e_s(A) > e_b(A)$*. (iii) The levels of wealth* $A_b^*$ *and* $A_s^*$ *at which the moral hazard problem is resolved under environmental bonding and mandatory insurance, respectively, satisfy* $A_b^* > A_s^*$*. (iv) The corresponding interests rates* $R_b(A)$ *and* $R_s(A)$ *are ranked thus:* $R_b(A) \geq R_s(A)$*.*

Proof.

(i) From (12) and (30), it is immediate that $A_b > A_s$. (ii) A comparison of (14) and (32) reveals that $e_s(A) > e_b(A)$ by virtue of the fact that $A_b > A_s$ and $\rho \in (0, 1)$. To prove part (iii), note that

$$A_s = I + l + \frac{W}{(1+\rho)} - \frac{B(v - W + (1+\rho)l)^2}{4(1+\rho)} = A_b^* - \frac{B(v - W + (1+\rho)l)^2}{4(1+\rho)}, \tag{33}$$

which implies that $A_b^* > A_s$. Next, note that

$$e_s(A_s) = \frac{B}{2}\{(v - W + (1+\rho)l)\} < e^* = \mathrm{B}\{v - W + l\} \tag{34}$$

while

$$e_s(A_b^*) = B\{(v - W + (1+\rho)l)\} > e^*. \tag{35}$$

But $A_b^* > A_s$ and $e_s(A_b^*) > e_s(A_s)$. Thus, by a simple intermediate value argument, there must exist an $A_s^* \in (A_s, A_b^*)$ such that $e_s(A_s^*) = e^*$. Part (iv): The incentive compatibility constraint under environmental bonding is

$$[v - R_b D_b(A)] - \wp'(e_b) = 0 \tag{36}$$

while under mandatory insurance, it is given by

$$[v - R_s D_s(A)] - \wp'(e_s) = 0 \tag{37}$$

The inequality $e_s(A) > e_b(A)$ and the convexity of $\wp(\mathrm{e})$ imply that $\wp'(e_s) > \wp'(e_b)$. But if $\wp'(e_s) > \wp'(e_b)$ then it must be the case that, $R_b D_b(A) > R_s D_s(A)$. Since $D_b(A) > D_s(A)$, however, a necessary and sufficient condition for the condition for $R_b D_b(A) > R_s D_s(A)$ to hold is that $R_b(A) \geq R_s(A)$. Q.E.D.

Part (*i*) shows that credit is more rationed under environmental bonding than it is under mandatory insurance. Part (*ii*) tells us that incentives are more pronounced under mandatory insurance than under environmental bonding. Part (*iii*) says that the moral hazard problem is resolved at a lower level of wealth under mandatory insurance than it is under environmental bonding. Part (*iv*) simply reinforces the conclusion from Part (*ii*): Since insolvency is more likely under bonding than it is under mandatory insurance, by virtue of the fact that $e_s(A) > e_b(A)$, the lender optimally demands a relatively higher rate of interest under the former policy.

The central tenet of Proposition 4 is that although environmental bonding and mandatory insurance are both *ex ante* policies, they are by no means equivalent. More precisely, the moral hazard problem is more severe under environmental bonding than it is under mandatory insurance. The reason for this is that the firm is relatively more financially constrained under environmental bonding.

## 4. Liability (LR)

Under this regulatory regime, in the event of an accident and bankruptcy, the victim always brings suit under common law to recover damages from the lender, whom we presume has deep pockets and cannot therefore file for bankruptcy. We assume that the judicial system is efficient in the following sense: if the victim brings suit against the lender, she is fully compensated for the damages they suffer. Of course, the doctrine of extended liability is not without its fair share of controversy. Proponents argue that imposing liability upon deep pocket lenders enhances cost recovery for victims of environmental harms when the primary producer of the harm is judgment-proof. Opponents counter by arguing that extending liability to lenders would reduce access to credit and impede socially valuable projects.

There are many dimensions along which environmental bonding and liability could differ. In this paper, however, we emphasize the relative effect of these instruments on the extent to which the firm is financially constrained. Environmental bonding burdens the wealth-constrained firm with additional borrowing out of the necessity to demonstrate compliance. More precisely, in order to undertake its project, the firm must borrow $D_b(A) = I + l - A$, where $l$ represents the effect of regulation. In contrast, by installing responsibility for the environmental on the lender, liability rule imposes no such additional financial burden. That is, the entrepreneur's borrowing requirement under liability excludes any effect of regulation and is given by $D_t(A) = I\text{-}A$. Thus, the firm is more financially constrained under environmental bonding than it is under liability rule.

The lender's expected payoff is given by

$$\pi_t(A; e, R) = eRD_t(A) - (1 + \rho)D_t(A) + (1 - e)(W - l) \tag{38}$$

Equation (38) says that with probability $e$, there is no damaging accident, in which case the lender receives $R$ on the loan $D_t(A)=I-A$. With probability (1-$e$) a damaging accident occurs, in which case the lender appropriates the firm's liquidation value, $W$, but being a financially responsible party, pays $l \leq h$ to the victim. It also says that regardless of whether or not the project causes a damaging accident, the lender foregoes $(1 + \rho)\ D_t(A)$ that it would have earned in an alternative asset.

The entrepreneur's expected payoff is

$$u_t(A; e, R) = e[v - RD_t(A)] - \wp\ (\mathrm{e}). \tag{39}$$

The optimal contract maximizes the expected net payoff of the entrepreneur, $u_t(.)$, subject to incentive compatibility for the entrepreneur, $e \in arg\ \max_{e'} u_t(A;\ \mathrm{e, R})$ and individual rationality for the lender, $\pi_t(A; e, R) \geq 0$. The solution to the borrower's problem is recorded in the following Proposition. Again, the proof and the interpretation are omitted.

**Proposition 5** *Suppose the lender is held strictly liable for the environmental harm caused by its borrower. The solution to the borrower's problem in this setting is characterized as follows:*

*(i) The set of borrowers and the optimal loan price are, respectively,* $S_t = [A_t, \bar{A}]$ *and* $R_t(A)$, *where*

$$A_t = I + \frac{l + W}{(1 + \rho)} - \frac{B(v - W + l)^2}{4(1 + \rho)}, \tag{40}$$

*and*

$$R_t(A) = \frac{(1 + \rho)}{e_t(A)} - \frac{\big(1 - e_s(A)\big)(W - l)}{e_t(A)(I - A)}. \tag{41}$$

*(ii)The optimal level of care is given by*

$$e_t(A) = \frac{B}{2}\left\{(v - W + l) + \left[\frac{4}{B}(A - A_t)\right]^{1/2}\right\} \tag{42}$$

An important conclusion from the previous section is that the socially efficient level of precaution can be implemented if $A$ is sufficiently large. This result extends to this section. To see this, rewrite (42) as

$$(v - W + l) - \frac{\{(1 + \rho)(I - A) - W + l\}}{e_t(A)} - \wp'\big(e_t(A)\big) = 0. \tag{43}$$

It is straightforward that $e_t(A) = e^*$ at $A = A_t^*$ where

$$A_t^* = I + h + \frac{W}{(1+\rho)}. \quad (44)$$

## 5. Comparison of Instruments

This section now evaluates the instruments in terms of their relative impact on (i) incentives, (ii) availability of credit and (ii) social welfare.

### 5.1. Impact on Incentives

An important result from the previous sections is that, under all the three mechanisms, the moral hazard problem is completely resolved when the entrepreneur is sufficiently wealthy, that is, when the entrepreneur has wealth $A \geq A_i^*$. Thus, in our model, entrepreneurs with $A > A_i^*$, *i=b,s,t,* overprotect, while those with $A < A_i^*$, *i=b,s,t,* underprotect. Naturally, one would like to know how $A_b^*$, $A_s^*$ and $A_t^*$ compare. The following Proposition shows that these critical wealth thresholds can be unequivocally ranked.

**Proposition 6** *Suppose that l=h. Then the wealth thresholds $A_b^*$, $A_s^*$ and $A_t^*$ that deliver the socially optimal levels of care are ordered thus: $A_b^* > A_s^* > A_t^*$.*

Proof.

Comparing equation (40) and equation (21), it is immediate that $A_b^* > A_t^*$. We know also that at $e_b(A_b^*) = e^*$. But $e_s(A_b^*) > e^*$. To prove this, rewrite the optimal level of care under a mandatory as

$$e_s(v - W + l) - (1+\rho)(I - A) + W - l - \rho l(1 - e_s) - e_s \wp'(e) = 0. \quad (45)$$

Now evaluating this expression at $A_b^*$ and imposing the condition *l=h*, we obtain

$$e_s(v - W + h) + \rho h + W - e_s \wp'(e) = 0. \quad (46)$$

But from equation (3)

$$e^*(v - W + h) - e^* \wp'(e) = 0. \quad (47)$$

Since $\wp(e)$ is convex, it follows that $e_s(A_b^*) > e^*$. Next, we know that $e_t(A_t^*) = e^*$. But $e_s(A_t^*) < e^*$.

Again, to prove this, we evaluate equation (45) using $A_t^*$ to obtain

$$e_s(v - W + l) - \rho l(1 - e_s) - e_s \wp'(e) = 0. \quad (48)$$

Comparing (47) to (48), we see that $e_s(A_t^*) < e^*$. Since $e_s(A)$ is increasing, $e_s(A_b^*) > e^* > e_s(A_t^*)$ and $A_b^* > A_t^*$, by the intermediate value argument, we can conclude that there exists an $A \in (A_t^*, A_b^*)$, call it $A_s^*$, such that $e_s(A_s^*,) = e^*$. The levels of *A* that yield $e^*$ under the three regimes are ordered thus: $A_b^* > A_s^* > A_t^*$. Q.E.D.

The main point of Proposition 6 is that, of the three regimes, liability rule (environmental bonding) requires the least (most) amount of minimum wealth threshold in order to deliver the socially efficient level of care. Evidently, $A_i^*$, *i=b,s,t,* and the distribution of wealth determine the proportion of entrepreneurs that implement at least the socially efficient level of precaution.

Following our notation, *1-F($A_i^*$)* indicates the fraction of entrepreneurs that overprotect. Since *1-F($A_t^*$)> 1-F($A_s^*$) >1-F($A_b^*$)*, Proposition 6, in essence, says that overprotection is more prevalent under liability rule than it is under financial assurance. Conversely, the tendency to underprotect is more pronounced under financial assurance.

To determine how the three schemes compare in terms of their impact on the level of precaution, we can to rewrite equations (14), (32) and (42) in the following useful form:

$$\{e_b(v - W + l) - (1+\rho)(I - A) + W - l - \rho l\}/e_b = \wp'(e_b) \tag{49}$$

$$\{e_s(v - W + l) - (1+\rho)(I - A) + W - l - \rho l(1 - e_s)\}/e_s = \wp'(e_s) \tag{50}$$

$$\{e_t(v - W + l) - (1+\rho)(I - A) + W - l\}/e_s = \wp'(e_t). \tag{51}$$

From (49) and (50), it is straightforward that $\wp'(e_b) < \wp'(e_s)$. The convexity of $\wp(.)$ then implies that $e_b(A) < e_s(\text{A})$. Similarly, comparing (50) and (51), we obtain $\wp'(e_t) > \wp'(e_s)$, which implies that $e_t(A) > e_s(\text{A})$. It follows therefore that $e_t(A) > e_s(\text{A}) > e_b(A)$. We can thus state:

**Proposition 7** *The optimal levels of precaution under the three regimes are ordered thus:* $e_t(A) > e_s(A) > e_b(A)$.

The gist of Proposition 7 is that, among the three instruments, the entrepreneurial moral hazard is most (least) severe under environmental bonding (liability rule). The logic behind this result has been alluded to previously. Under environmental bonding the firm is compelled to borrow more and repay a correspondingly higher amount compared to the other mechanisms. This means that the incentives for the entrepreneur to exercise care are dampened by the larger share of the surplus that is appropriated by the lender. By contrast, liability rule imposes no such additional burden on the entrepreneur. Although the responsibility for the environmental harm is shifted to the lender under this rule, the best that the lender can do to cushion itself against this downside risk is to adjust the *cost* of the loan (i.e., interest rate). In other words, the lender lacks the latitude to adjust the *amount* of financing, which is relatively more deleterious to incentives. Mandatory insurance is similar to environmental bonding in that it compels the entrepreneur to borrow to finance both the investment and the cost of the environmental liability. However, it differs from environmental bonding in that it imposes a less onerous borrowing and repayment burden on the entrepreneur. More precisely, under mandatory insurance, the entrepreneur need not finance the entire liability amount. Rather, because liability insurance is purchased at an actuarially fair amount, the additional financial burden that regulation engenders is equivalent to the expected liability.

## 5.2. Impact on Availability of Credit

An important hallmark of friction in the financial system is the extent of credit rationing. How then does the instrument in use affect the extent to which credit is rationed in our framework? The following proposition discusses the relationship between the proportion of entrepreneurs who are able to finance their projects and the instrument that is in place when *l=h.*

**Proposition 8** *The critical values $A_b$, $A_s$ and $A_t$ below which borrowing is not feasible under environmental bonding, mandatory insurance and liability rule, respectively, satisfy $A_b$> $A_s$> $A_t$ .*

Proof.

From (12) (30) and (40), it is straightforward that $A_b > A_s$ and $A_b > A_t$. Thus, to complete the proof, we only need to show that $A_s - A_t > 0$. Recall that

$$e_s(A) = \frac{B}{2}(v - W + (1+\rho)l) + \frac{B}{2}\left[\frac{4}{B}(A - A_s)\right]^{1/2} \tag{52}$$

and

$$e_t(A) = \frac{B}{2}(v - W + l) + \frac{B}{2}\left[\frac{4}{B}(A - A_t)\right]^{1/2} \tag{53}$$

We also know, from Proposition 4, that $e_t(A) > e_s(A)$ . Since $\frac{B}{2}(v - W + (1+\rho)l) > \frac{B}{2}(v - W + l)$, however, the condition $e_t(A) > e_s(A)$ will hold, if and only if $A_t < A_s$. Combining these results now yield $A_b > A_s > A_t$.Q.E.D.

Poor entrepreneurs (i.e., those endowed with $A \in [0, A_t]$ are not funded at all. Those with $A \in [A_t, A_s)$ are only rich enough to qualify for funding under liability rule. Entrepreneurs with $A \in [A_s, A_b)$ get funding under both liability rule and mandatory insurance. Only entrepreneurs with $A \in [A_b,\ \bar{A}\ ]$ are financed under all the three mechanisms. Proposition 8 simply says that, among all the three damage recovery instruments, credit is rationed the most (least) under environmental bonding (liability rule).

## 5.2. Welfare Implication

We conclude this section by evaluating social welfare under the three schemes. Social welfare under mechanism *i*, , *i=b,s,t,* is given by

$$S_i(\text{A}) = \int_{A_i}^{\bar{\bar{A}}} \{e_i(A)(v - W + h) + W - h - (1+\rho)I - \wp\ (e_i(A))\ \} f(A)dA \tag{54}$$

Differentiating $S^i$(A) with respect to *A* we have

$$S_i'(\text{A}) = \int_{A_i}^{\bar{\bar{A}}} \{(v - W + h) - \wp\ '(e_i(A))\ \} e_i'(A) f(A)dA. \tag{55}$$

Since $e_i'(A) > 0$, the sign of $S_i'$(A) crucially depends on the sign of the term in curly brackets. Given equation (3) and the convexity of $\wp\ (e_i(A))$, equation (55) implies that

$$S_i'(\text{A}) \begin{cases} > 0\ if & A < A_b^* \\ = 0\ if & A = A_b^* \\ < 0\ if & A > A_{b.}^* \end{cases} \tag{16}$$

Furthermore,

$$S_i''(\text{A}) = \int_{A_i}^{\bar{\bar{A}}} \{[(v - W + h) - \wp\ '(e_i(A))]\ e_i''(A) - \wp\ ''(e_i(A))[e_i'(A)]^2\} e_i''(A) f(A)dA < 0. \tag{57}$$

These results together imply that the social welfare function under limited information $S_i$(A) is non-monotonic in *A*. This situation is depicted in Figure 1. Social welfare is increasing in *A* so long as

$A \leq A_i^*$. Social welfare is at a maximum when $A = A_i^*$. Beyond $A_i^*$, social welfare actually diminishes because there is overprotection, relative to the social optimum. Note that $S_i$(A) never exceeds $S^*$, the social optimum.

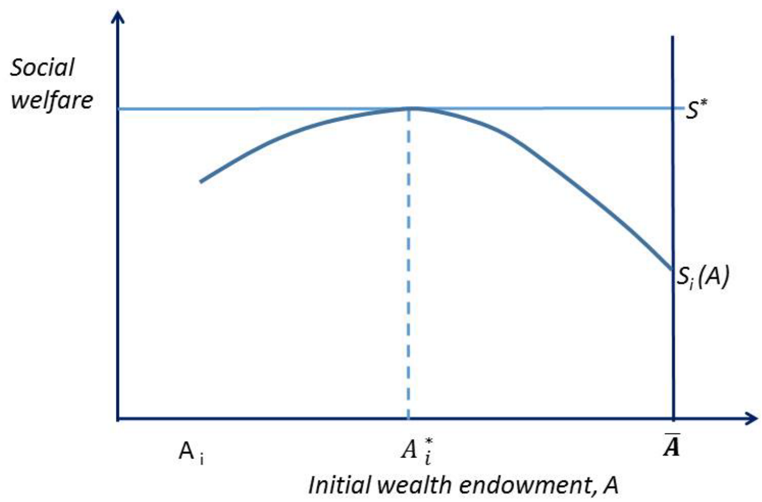


**Figure 1**. Social Welfare and initial wealth endowment

Of particular interest is how social welfare compares between the three instruments. To address this question, we sketch the social welfare functions corresponding to the three schemes in Figure 2. Three salient points are worth noting: First, the $S_t$(A) curve cuts the other two curves from above by virtue of the fact that the moral hazard problem is resolved at a relatively lower level of wealth under liability rule; Second, the $S_b$(A) curve cuts the other two curves from below because the moral hazard problem is resolved at a relatively higher level of wealth under environmental bonding; Third, the $S_s$(A) curve cuts the $S_t$(A) curve from below, but intersects $S_b$(A) curve from above because the moral hazard problem is resolved at an intermediate level wealth under mandatory insurance.

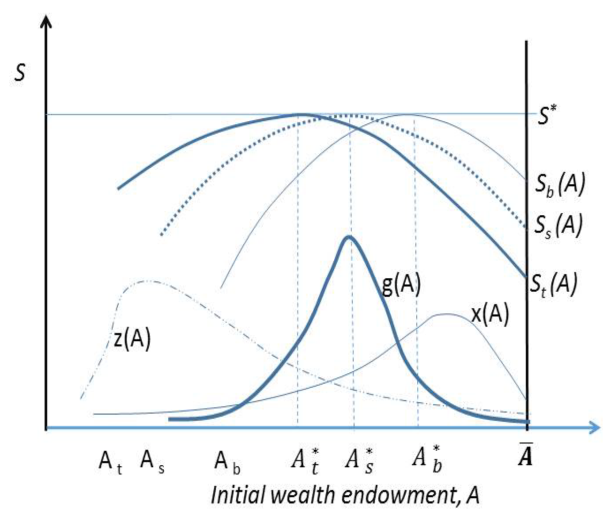


**Figure 2**. Social Welfare and the distribution of wealth

The structure of the $S_i$(A) curves as discussed in the foregoing implies that the relative ranking of the three mechanisms crucially depends on the level of wealth: (a) at a lower level of wealth, liability yields the best social outcome while environmental bonding yields the least; (b) at higher levels of wealth, the ranking of the instruments is completely reversed, with environmental bonding yielding the best outcome and liability delivering the worst; (c) when wealth is in the intermediate range, mandatory insurance is the best of the three mechanisms.

It turns out the ranking of instruments does not only depend on the *level* of wealth as emphasized in the foregoing. It may also be affected by the *distribution* of entrepreneurial wealth. To see this, we have superimposed three wealth distributions functions in Fig.2. As can be seen, these distributions differ in terms of their skewness. We observe that if the mass of distribution is concentrated in upper end-point, then on a purely social welfare criterion, the regulator should prescribe assurance bonds. On the other hand, if the mass of distribution is concentrated in the lower end of the wealth distribution, then the regulator should mandate a liability rule. A more "normal" distribution (i.e., one where wealth is somewhat evenly distributed among entrepreneurs) might call forth for mandatory insurance.

## 6. Discussion and Policy Implication

*Ex ante* financial assurance schemes (i.e., environmental bonding and mandatory liability insurance) and *ex post* system of tort liability may form part of a regulator's "tool kit" for resolving the judgment-proof problem. These instruments share a common regulatory motive of assuring the recovery of damages for the victims. Often, however, they are imposed on firms that are financially constrained in the sense that they must rely on imperfect capital markets to finance their projects. Of course, the main source of capital market imperfections is moral hazard on the part of the firm. A key question then is how the imposition of these instruments affects the interaction between the firm's financial decision problem and market imperfections and how this interaction in turn shapes economic and environmental outcomes. Does the introduction of these instruments exacerbate or lessen the frictions in the financial markets? Do they have distinct economic and environmental outcomes?

One hallmark of frictions in the financial market is credit rationing. The model here shows that, regardless of the instrument in place, credit rationing can exist. More precisely, in equilibrium, the set of firms are divided into two different groups. Wealthy firms receive loans, while those with little wealth are shut out of the credit market. Thus, our model relies on wealth to produce credit rationing. Intriguingly, the extent of credit rationing crucially depends on the instrument used. More precisely, of the three instruments, credit is rationed the most (least) under environmental bonding (liability). Thus one can argue that financial market frictions are not impervious to the conduct of environmental policy.

Comparable rationing results are not feasible in models by Shavell (2005), Farber (1991) and van't Veld and Shogren (2012) since these studies preclude the firm's financial decision problems and hence the working of the credit market. In Heyes (1996), where only one instrument; namely, liability, is analyzed, credit rationing is produced by the agency problem of adverse selection. In particular, only firms with sufficiently low risk apply for loans. At first glance, this result might appear to have little in common with our finding that only particularly poor entrepreneurs voluntarily experience credit rationing. The parallels become clear, however, if one recognizes a common underlying principle: in both studies, credit is rationed to "low quality" borrowers. In Heyes (1996), quality takes the form of risk of an accident with high risk firms representing low quality. In our paper, cash poor firms borrow more, have a higher probability of insolvency and hence represent low quality.

The idea that credit is rationed to relatively low quality borrowers stands in stark contrast to Stiglitz and Weiss (1981) and Smith and Stutzer (1989), where the rationing of credit is to relatively high quality borrowers. The reason for this has to do with differences in settings. The environment in Stiglitz and Weiss (1981) and Smith and Stutzer (1989) is that of adverse selection, where borrowers are observationally indistinguishable. In our model, by contrasts, borrowers have identifiable characteristics; that is, there is no adverse selection and borrowers can be distinguished according to their levels of wealth. Our result here thus parallels results in models that have no adverse selection (see, for example, Biais & Mariotti, 2009; Aghion & Bolton, 1997).

A well-known result in corporate finance literature is that a firm's financial constraint will affect its investment incentives. In particular, a financially constrained firm will invest less than an identical unconstrained firm (see, for example, Hubbard, 1998). Furthermore, the more financially constrained the firm is, the less pronounced will its investment incentives. This paper tests the central tenet of this proposition by focusing on the interaction among environmental regulatory instruments, financing constraint and the incentive to undertake care. In general, our results tend to give support to the received theory. Environmental bonding imposes the greatest direct financial constraint on the firm while liability rule imposes none. As a consequence, incentives are, unequivocally, strongest (weakest) under liability (environmental bonding).

A pertinent policy question has to do with which instrument delivers the best social outcome and should therefore be deployed as the optimal regulatory tool. The results of the model presented above are not unequivocal in this regard. In particular, we find that the relative performance of the schemes, in terms of their impact on social welfare, crucially depends on the level and dispersion of wealth among individual borrowers. This result underscores the folly of a standardized one-size-fits-all regulatory structure, one that implicitly presumes that firms are identical. An efficient regulatory regime must take cognizance of firm heterogeneity and structure the damage recovery tools accordingly. This might involve the regulator, first, classifying entrepreneurs according to their levels of wealth and then prescribing a distinct instrument for each entrepreneurial class as follows: (a) mandating liability rule for entrepreneurs with low wealth, (b) prescribing assurance bonds for entrepreneurs with high wealth and (c) requiring insurance for firms with intermediate wealth.

## 7. Conclusion

This paper uses a simple lending model to examine the implications of various schemes designed to address the judgment-proof problem. More precisely, we investigate the relative impact of environmental bonds, mandatory insurance and liability rule. The model is based on a simple moral hazard problem between borrowers and their financiers.

The model demonstrates that the type of instrument used has implications for the extent of credit rationing, incentives and social welfare. When it comes to the first two measures, the ranking of the instruments is unequivocal: Bonds perform the worst with respect to credit rationing and the level of precaution that is optimally induced; liability yields the best outcome for credit rationing and incentives; mandatory insurance is somewhere in between bonds and liability.

Such lack of ambiguity does not extend to the social welfare criterion, however. The reason for this is that the social welfare function is non-monotonic in entrepreneurial wealth and the moral hazard problem is resolved at different levels of wealth depending on the instrument in use. As a consequence, the relative performance of the schemes in terms of their impact on social welfare crucially depends on the level of entrepreneurial wealth. Liability yields the best social outcome at a lower level of wealth; environmental bonding delivers the highest level of social welfare at higher levels of wealth; mandatory insurance is better than the other two mechanisms when wealth is in the intermediate range. These results have an intriguingly novel implication for instrument choice. They suggest an efficient regulatory regime might take into account the entrepreneur's wealth.

While the model provides important insights on the impact of regulating environmental externalities, there remain some interesting extensions. To keep things simple, we have abstracted from modelling risk preferences presuming, instead, that all parties are risk neutral. A natural extension might admit alternative specification of risk preferences. A typical entrepreneur may not hold a large portfolio of projects and may therefore be unable to diversify away all risks associated with a project. Thus, it may be appropriate to model the entrepreneur as a risk-averse economic agent. The paper considered bonds, insurance and liability as alternative means to assure recovery of damages. In principle, however, these instruments could be employed jointly. Future work might therefore consider how these results would change if the instruments were employed in combination rather than exclusively.

The paper assumed that the borrower has all the bargaining power. This is based on the premise that capital markets are competitive and that lenders compete with each other in the provision of both credit and screening services. A useful extension might consider how these results would change if lenders did not compete in their role as financiers and could dictate the terms of the financial contract. Another important caveat concerns our assumption that the lender cannot monitor the agent. A useful extension might consider a setting where lenders actively monitor borrower behaviour in order to reduce the moral hazard problem. We hope that such extensions will enhance rather than undo the insights presented here.

## References

[1] Aghion, P., & Bolton, P. (1997). A theory of trickle-down growth and development. *Review of Economic Studies*, *64*(2), 151 -172. doi:10.2307/2971707

[2] Balkenborg, D. (2001). How liable should a lender be? The case of judgment-proof firms and environmental risk: Comment. *American Economic Review*, *91*(3), 731-738. doi:10.1257/aer.91.3.731

[3] Biais, B., & Mariotti, T. (2009). Credit, wages, and bankruptcy laws. *Journal of the European Economic Association*, *7*(5), 939-973. doi:10.1162/JEEA.2009.7.5.939

[4] Boyd, J. (2002). Financial responsibility for environmental obligations: Are bonding and assurance rules fulfilling their promise? In T. Swanson (ed.), *Research in law and economics (Vol. 20) - An introduction to the law and economics of environmental policy: Issues in institutional design* (pp.417 – 485). UK: Emerald GROUP Publishing Limited.

[5] Boyd, J., & Ingberman, D. E. (1997). The search for deep pockets: Is “extended liability” expensive liability? *Journal of Law, Economics, and Organization*, *13*(1), 232-258.

[6] Boyer, M., & Laffont, J.-J. (1997). Environmental risks and bank liability. *European Economic Review*, *41*(8), 1427-1459. doi:10.1016/S0014-2921(96)00034-7

[7] Dana, D. A, & Wiseman, H. J. (2014). A market approach to regulating the energy revolution: Assurance bonds, insurance, and the certain and uncertain risks of hydraulic fracturing. *Iowa Law Review*, *99*(4), 1523-1593.

[8] Dionne, G., & Spaeter, S. (2003). Environmental risk and extended liability: The case of green technologies. *Journal of Public Economics*, *87*(5-6), 1025-1060. doi:10.1016/S0047-2727(01)00160-8

[9] Farber, S. (1991). Regulatory schemes and self-protective environmental risk control: A comparison of insurance, liability, and deposit/ refund systems. *Ecological Economics*, *3*(3), 231-245. doi:10.1016/0921-8009(91)90034-C

[10] Feess, E., & Hege, U. (2002). Safety regulation and monitor liability. *Review of Economic Design*, *7*(2), 173-185. doi:10.1007/s100580200075

[11] Feess, E., & Hege, U. (2003). Safety monitoring, capital structure, and “financial responsibility”. *International Review of Law and Economics*, *23*(3), 323-339. doi:10.1016/j.irle.2003.09.008

[12] Ferreira, D., Suslick, S., Farley, J., Costanza, R., & Krivov, S. (2004). A decision model for financial assurance instruments in the upstream petroleum sector. *Energy Policy*, *32*(10), 1173-1184. doi:10.1016/S0301-4215(03)00080-6

[13] Gerard, D., & Wilson, E. J. (2009). Environmental bonds and the challenge of long-term carbon sequestration. *Journal of Environmental Management*, *90*(2), 1097-1105. doi: doi:10.1016/j.jenvman.2008.04.005

[14] Heyes, A. G. (1996). Lender penalty for environmental damage and the equilibrium cost of capital. *Economica*, *63*(250), 311-323.

[15] Hubbard, R. G. (1998). Capital-market imperfections and investment. *Journal of Economic Literature*, *36*(1), 193-225.

[16] Hutchinson, E., & van't Veld, K. (2005). Extended liability for environmental accidents: What you see is what you get. *Journal of Environmental Economics and Management*, *49*(1), 157-173. doi:10.1016/j.jeem.2004.03.003

[17] Katzman, M. T. (1988). Pollution Liability Insurance and Catastrophic Environmental Risk. *Journal of Risk and Insurance*, *55*(1), 75-100.

[18] Lewis, T. R., & Sappington, D. E. M. (2001). How liable should a lender be? The case of judgement-proof firms and environmental risk: comment. *The American Economic Review*, *91*(3), 724-730. doi: 10.1257/aer.91.3.724

[19] Mathis, M. L., & Baker, P. B. (2002). Assurance bonds: A tool for managing environmental costs in aquaculture. *Aquaculture Economics & Management*, *6*(1-2), 1-17. doi:10.1080/13657300209380300

[20] OECD. (2003). *Environmental risks and insurance: A comparative analysis of the role of insurance in the management of environment-related risks*. France: OECD Publishing. doi:10.1787/9789264105522-en

[21] Pitchford, R. (1995). How liable should a lender be? The case of judgement-proof firms and environmental risk. *American Economic Review*, *85*(5), 1171-1186.

[22] Shavell, S. (1986). The judgement proof problem. *International Review of Law and Economics*, *6*, 45-58.

[23] Shavell, S. (2005). Minimum asset requirements and compulsory liability insurance as solutions to the judgment-proof problem. *RAND Journal of Economics*, *36*(1), 63-77.

[24] Shogren, J. F., Herriges, J. A., & Govindasamy, R. (1993). Limits to environmental bonds. *Ecological Economics*, *8*(2), 109-133. doi:10.1016/0921-8009(93)90040-D

[25] Smith, B. D., & Stutzer, M. J. (1989), Credit Rationing and Government Loan Programs: A Welfare Analysis. *Real Estate Economics*, *17*(2), 177–193. doi:10.1111/1540-6229.00483

[26] Stiglitz, J. E., & Weiss, A. M. (1981). Credit rationing in markets with imperfect information. *American Economic Review*, *71*(3), 393-410.

[27] van't Veld, K., & Shogren, J. F. (2012). Environmental federalism and environmental liability. *Journal of Environmental Economics and Management*, *63*(1), 105-119. doi:10.1016/j.jeem.2011.05.004

## Appendix

### Proof of Proposition 1

Since $\wp(e)$ is differentiable in $e$, (ii) implies that $e$ satisfies the conditions

$$[v - RD_b(A)] - \wp'(e) \leq 0 \tag{A1}$$

$$e\{[v - RD_b(A)] - \wp'(e)\} = 0\,, \tag{A2}$$

where $D_b(A)$ is defined by equation (6). In what follows, we assume that $e$ is positive, so (A.1) holds with strict equality. This means that we can replace equation (11) with the condition $v - RD_b(A) - \wp'(e) = 0$.

The Lagrangian for the borrower's problem is

$$\mathcal{L} = e[v - RD_b(A)] - (1-e)l - \wp(\mathrm{e}) + \lambda[v - RD_b(A) - \wp'(e)] \\ +\mu\{eRD_b(A) - (1+\rho)D_b(A) + (1-e)W\}, \tag{A3}$$

where $\lambda$ and $\mu$ are corresponding Lagrange multipliers. The first-order conditions are as follows:

(i) With respect to $R$, $-e-\lambda+\mu e= 0$ which implies $\mu = (1 + \lambda/e)>0$. Hence the lender's participation constraint must be binding. This implies that lenders earn zero profits in equilibrium.

(ii) With respect to $e$, $\{v - RD_b(A) - \wp'(e)\}-\lambda\wp''(e) + \mu\{RD_b(A) - W\}= 0$. From the incentive compatibility constraint, the first term in curly brackets is equal to zero. This implies that, $\div= +\mu\{RD_b(A) - W\}/\wp''(e)$. Since $\mu >0$, it follows that $\lambda >0$. Hence, the borrower's incentive constraint binds.

Now, making use of the binding incentive and participation constraints, we obtain the polynomial

$$\frac{e^2}{B} - e(v - W + l) + (1+\rho)(I + l - A) - W = 0 \tag{A4}$$

This equation has real solutions if $[v - W + l]^2 - 4\,\{(1+\rho)(I + l - A) - W\,\}/\mathrm{B} \geq 0$ or $A \geq A_b$, where

$$A_b = I + l - \frac{W}{(1+\rho)} - \frac{B(v - W + l)^2}{4(1+\rho)}\,, \tag{A5}$$

which is equation (12) in the text. In other words, all entrepreneurs with wealth $A < A_b$ are credit rationed in that they are not able to borrow, even if they want to borrow. For $A \geq A_b$, the quadratic equation has two roots

$$\frac{B}{2}\left\{(v - W + l) \pm \left[\frac{4}{B}(A - A_b)\right]^{1/2}\right\},$$

but the borrower prefers the greater one (i.e., the one associated with the lowest interest rate), which is equation (14) in the text. Next, substituting for $e$ in the binding participation constraint yields equation (13) in the text.

## Proof of Proposition 2

The Lagrangian for the borrower's problem is

$$\mathcal{L} = e[v - RD_s(A)] - \wp(\mathrm{e}) + \lambda[v - RD_s(A) - \wp'(e)] \\ +\mu\{eRD_s(A) - (1+\rho)D_s(A) + (1-e)W\} + \xi[pl - (1-e)l],$$

where $\lambda$, $\mu$ and $\xi$ are corresponding Lagrange multipliers. The first-order conditions include:

$$\frac{\partial \mathcal{L}}{\partial R} = -e-\lambda+\mu e = 0 \quad \text{(A6.i)}$$

$$\frac{\partial \mathcal{L}}{\partial e} = \{\, v - RD_s(A) - \wp'(e)\} - \lambda \wp''(e) + \mu\{RD_b(A) - W\} + \xi l = \ 00 \quad \text{(A6.ii)}$$

$$\frac{\partial \mathcal{L}}{\partial p} = -eR-\lambda R + \mu\{eR-(1+\rho)\} + \xi = 0. \quad \text{(A6.iii)}$$

From A6.i, we obtain $\mu = (1 + \lambda/e) > 0$. Hence the lender's participation constraint must be binding. Making use of A6.i, we can rewrite A6.iii as $-\mu(1+\rho) + \xi = 0$, which, by virtue of the fact that $\mu>0$, implies that $\xi>0$. Hence, $pl = (1-e)l$ and insurance coverage is provided at an actuarially fair price. From A6.ii, we obtain $\lambda = \frac{\mu\{RD_b(A)-W\}+\xi}{\wp''(e)} > 0$ since $\mu>0$ and $\xi>0$. Thus, all the constraints are binding.

Now, making use of the binding incentive and participation constraints, we obtain the polynomial

$$\frac{e^2}{B} - e(v - W + (1+\rho)l) + (1+\rho)(I + l - A) - W = 0 \quad \text{(A7)}$$

The rest of the proof is analogous to the proof of Proposition 1, and is therefore omitted.