

# Moral Hazard and Debt Maturity

**Gur Huberman**  
Columbia Business School

**Rafael Repullo**  
CEMFI

February 22 2011  
Preliminary and incomplete

## **Abstract**

Having borrowed the necessary funds, a bank may choose its assets (or modify them) to be excessively risky; this is a form of moral hazard. Consequently the lenders may demand high risk premia for the loans they extend. The high risk premia may lead the bank's equity owners to select even riskier assets or forego positive present value projects altogether. The maturity structure of the bank's debt may make a difference: Short-maturity debt which has to be rolled over can act as a disciplinary device if prior to the debt's renewal there is a signal indicating the likelihood of the bank running into trouble. The cost of funding with risky short-term debt is premature liquidation. The paper offers a model of these considerations, studies the conditions under which one maturity structure is preferred over the other and shows that short-term debt may be the dominant, or even the only way to secure funding

*JEL Classification:* G21, G32

*Keywords:* Short-term debt, long-term debt, wholesale financing, inefficient liquidation.

We are grateful for comments of Patrick Bolton, Charles Calomiris, Eddie Dekel, Paul Kupiec, John Moore, Lev Ratnovski, Anatoli Segura, Javier Suarez and Mark Westerfield, as well as those of seminar audiences at CEMFI, Columbia Business School, Tel Aviv University, Toulouse School of Economics, the 2009 Latin American and the 2010 North American Winter Meetings of the Econometric Society. Financial support from the FDIC is gratefully acknowledged. E-mail: gh16@columbia.edu, repullo@cemfi.es.

“It is difficult to establish any archetype for failure. Banks with high capital ratios imploded while those with lower ratios survived. Plain-vanilla retail banks blew up while some black-box trading shops prospered. Both small and big firms collapsed. Yet there was a common ingredient in most failures: an over-reliance on (short-term) wholesale borrowing.” *The Economist*, September 5, 2009.

“Borrowers design their financial structures to their own benefit, and one cannot presuppose that dangerous forms of debt constitute suboptimal liability structures.” Jean Tirole, *American Economic Review*, 2003.

## 1 Introduction

Funding long-term projects with short-term debt risks failure to roll over the debt. Such failure can happen if in the interim adverse news is announced about the projects’ final payoff or if short-term lenders have better or more urgent uses for their money. In that case the projects are likely to be liquidated and the initial creditors end up collecting the proceeds. Why then fund long-term projects with short-term rather than long-term debt?

A voluminous banking literature that analyzes maturity intermediation focuses on liquidity risk: short-term lenders may not refinance an enterprise because of changes in the lenders’ or market-wide financial needs or opportunities. This paper is different. Abstracting from this possibility this paper studies the implications of short-term lenders not refinancing an enterprise because of adverse news regarding the borrower.

Invoking the borrower’s freedom to choose the riskiness of the projects – a moral hazard problem – this paper focuses on the impact of debt maturity on that choice. By studying the often overlooked risk mitigating benefit of short-term funding this paper sounds a word of caution to recent proposals favoring the lengthening of intermediaries’ debt maturities.

Central to the paper is the analysis of the equity holders' optimal decision at the outset. At that point they know that short-term debt will require refinancing and that failure to refinance will result in inefficient liquidation, i.e., deadweight loss. The paper's main point is that in the presence of the moral hazard problem in the choice of project risk, the anticipation of refinancing needs acts as a disciplining device that inhibits the equity holders' pursuit of high-risk projects and thereby can render short-term superior to long-term debt financing. Thus, the trade-off is between the disciplining benefits of risky short-term debt versus the risk of inefficient liquidation that it entails.

The analysis demonstrates that risky short-term debt may be superior to long-term debt even when the latter is feasible. In that case the face value of the short-term loan will be lower than that of the alternative, long-term loan. Due to familiar risk-shifting problems, the feasibility of long-term debt financing is not guaranteed; however, when the equity holders are unable to fund the projects with a long-term loan, they may still be able to fund it with a risky short-term loan. In fact, a risky short-term loan may be so beneficial that sometimes it is optimal to borrow short-term more than the amount necessary to fund the projects and pay out the excess amount as dividend to the share holders. The downside of risky short-term funding is that the probability of inefficient liquidation is positive.

The borrower modeled here has three attributes of a bank: it funds itself through borrowing (there is no equity capital), it can nimbly modify the risk profile of its assets, and the assets can be deployed to other sectors only at great cost. (Thus, liquidation value is modeled as a fraction of the continuation value of the assets.)

To some extent the model is inspired by pre-modern bank structures: the equity was privately and narrowly held, there was no tax subsidy to debt and deposit insurance was unheard of. Nonetheless, banks borrowed short-term and extended medium- and long-term loans. Today, in fact, uninsured commercial paper is widely used even in the presence of deposit insurance. The analysis establishes an incentives-based rationale for the possible superiority of short-term bank debt.

## 1.1 Synopsis

The model proposed here illustrates the incentive effects of debt maturity on risk taking and risk shifting. With the exception of the benchmark case of equity financing, a firm must be debt-financed and decision making - the choice of the riskiness of the firm's assets - is in the hands of the shareholders. The comparison between the incentive effects of short-term and long-term debt is the main concern.

The presentation begins with the first-best, equity financing case, proceeds to the case of a single period debt financing (later re-interpreted as long-term debt) and then offers a model of short-term debt. That model has an intermediate period in which information about the eventual outcome is revealed and, following that revelation, the borrowing firm has to repay the existing creditors by issuing another short-term debt if it can. If it cannot fully repay the existing creditors, they liquidate the firm and collect its liquidation value.

In all three funding versions of the model the equity holders choose the risk level of the assets after the firm has raised the necessary funds, in anticipation of future allocations of the payoffs. The misalignment of the interests of the decision makers (the equity holders) and that of the creditors will lead to risk shifting (a choice of higher risk level than the socially optimal one) possibly to the extent of foregoing all positive present value projects.

The model has few and simple ingredients: a binary payoff outcome with the level of the successful outcome decreasing with its probability, the equity holders choose the success probability  $p$ ; for the version with long-term debt, the equity holders choose initially the face value of the debt  $B$  and the initial dividend  $D$  and, once the funds for investment have been raised, the equity holders choose the project's success probability  $p$ ; for the version with short-term debt, the equity holders initially choose the face value of the first short-term debt  $M$  and the initial dividend  $D$  and then choose the project's success probability  $p$ . A binary signal indicating whether the project is likely to succeed or fail - the probability of the signal being accurate is  $q$  - appears at an intermediate period. The market refinances the initial short-term debt if the signal is sufficiently encouraging. Otherwise the firm liquidates for liquidation value  $L$  which is a fraction  $\lambda$  of the continuation value. In both versions, if the

project reaches a successful conclusion, the final payoff to the equity holders is whatever is left after the creditors have been paid in full.

The tension in the model arises because the equity holders make the key decision (choice of the success probability  $p$ ) but are the residual claimants behind the creditors. The riskier the project, the higher the final payoff (if it materializes) and therefore the more favorable it is to the equity holders and the less favorable it is to the creditors, so the equity holders are induced to choose higher levels of risk than the socially optimal one. The tension is stronger the bigger the amount owed. Therefore such circumstances can lead to the project not being funded at all.

Incentives can be better aligned in the presence of an intermediate period signal indicating whether the project is likely to succeed or fail. A device that punishes equity holders if the signal is bad may mitigate their appetite for risk in the first place. Such a device is short-term debt which matures following the revelation of a signal about the eventual payoff. The short-term debt must be rolled over for the firm to survive. If the signal is bad the firm liquidates and the equity holders receive nothing.

The model's apparent simplicity notwithstanding, the set of considerations for and against short-term debt is complex.

Short-term debt which is safe, i.e., pays in full following the signal's appearance, has no advantage over long-term debt: in its presence the incentives faced by the equity holders in their choice of the success probability are as if the project was funded by long-term debt. Short-term debt can be effective in improving these incentives only if it is risky, i.e., the first-period creditors are not paid in full if the signal is bad; in that case the project is terminated and the shareholders forego potential future profits. Thus, a first-period bankruptcy punishes the shareholders for having chosen an excessive risk level.

Once the intermediate-period signal is revealed, liquidation is inefficient since the liquidation value is merely a fraction of the continuation value. Nonetheless, if the signal is bad, liquidation does take place because the first-period creditors cannot coordinate orderly resolution. At the outset, the possibility of this liquidation disciplines the equity holders to select lower risk than they would otherwise select.

The first-period creditors receive the liquidation value (if the signal is bad) or the face value of the debt (if the signal is good.) A relatively high first-period liquidation value is associated with a relatively low face value of the first-period debt, which in turn delivers a low face value of the second –period debt. The latter determines the amount the equity holders collect if the project is not liquidated after the first period and is ultimately successful. The bigger their share of the ultimate allocation, the stronger their incentive to mitigate the project’s risk.

The equity holders own the project at the outset and therefore the expected value of their income is the project’s expected value – which depends on their choice of the success probability – minus the required initial investment. The equity holders are paid as residual claimants of the project’s payoff (if it reaches that stage) and as recipients of an initial dividend.

## 1.2 Literature Review

One risk of short-term funding of long-term projects is that the lenders may find better or more urgent use of the money and refuse to refinance the projects. This risk, often called liquidity risk, plays a major role in most papers that analyze short-term funding. The model presented here is an exception in that lenders have no demand for liquidity.

Liquidity risk is the focus of the seminal paper by Diamond and Dybvig (1983) who show how banks may efficiently insure this risk, but may be subject to runs by demand depositors suspecting that other depositors may want to withdraw their funds and therefore render the bank illiquid. Extending Diamond and Dybvig, Jacklin and Bhattacharya (1988) study informationally-based bank runs. They compare and contrast deposit-based and market-based funding mechanisms, but do not focus on the term structure of the bank’s liability.

Myers and Rajan (1998) point a challenge to financial intermediaries: the liquidity of their assets (i.e., the ease with which they can be traded) suggests the difficulty with which they can commit to a strategy that protects their creditors’ interests. The present model points out that short term liabilities may help mitigate this problem.

Calomiris and Kahn (1991) study a model of bank finance in which the bank can abscond

with the funds ex post. The incentive to abscond is greater with lower return realizations. In this context it is optimal to use short-term demandable debt, because it gives investors the option to force liquidation at an interim date when they observe a bad signal. Short-term debt does not operate as a discipline device on ex ante risk-taking, which is a key mechanism in the present model.

Building on Myers (1977), Flannery (1994) points out that financial intermediaries can easily modify the risk profile of their assets. Contracts preventing such modifications are difficult to write and enforce, so a reasonable alternative for the intermediary is to issue short-term debt. The need to roll over the debt will act as a disciplinary device that may restrain the intermediary from increasing the risk of its assets to benefit its shareholders at the expense of its creditors. (Barnea, Haugen and Senbet, 1980, entertain a similar intuition.) Flannery's work does not offer a full model of the interaction between the risk-shifting incentives with the liquidation value and the quality of information available at the intermediate stage nor does it suggest circumstances in which short-term risky debt is the only viable source of debt funding.

Leland (1998) offers a dynamic, open-ended model of the joint determination of capital structure, including debt maturity, and investment risk when debt entails tax benefits in good times and default costs in bad times. An added ingredient is agency costs – the ability of equity holders to choose the risk at which the firm's asset value evolves. Leland's model abstracts from the determination of the investment level and from the possibility that investment risk and expected payoff are related. These ingredients are crucial in the model presented here.

Hart and Moore (1994) offer a dynamic, deterministic model of entrepreneurial debt in which debt service is paid over time. The entrepreneur, whose presence is necessary for a project's success, initially lacks the funds to pursue the project. The project's payoff would be reduced to its liquidation value if the entrepreneur quits. The payment to the investor compensates him for the initial funds he provides without be so punitive as to tempt the entrepreneur to quit. Some agreed-upon payment profiles are interpreted as short-term debt. Hart and Moore (1995) explore the role of long-term debt in preventing

self-interested management from financing unprofitable investments. In their model management and shareholders' interests are not aligned because of management's empire building tendencies.

In reviewing the main issues, Hart (2001) writes: "A rough summary is that shareholders have decision rights as long as the firm is solvent, while creditors acquire decision rights in default states." The present paper adopts the approach that as long as the firm is solvent, decisions are made to maximize shareholders' value, whereas once it defaults, creditors make decisions to enhance their value. Renegotiations are ruled out, either because creditors are too dispersed and therefore cannot coordinate among themselves, or because they are concerned not to acquire a reputation for softness which may hurt them in other relations.

Diamond and Rajan (2001) note the tension between two of the primary functions of banks: making illiquid loans to borrowers and providing liquidity to demand depositors. The depositors may demand liquidity exactly when the bank can provide the funds only at great cost. They construct a model in which these two activities are, perhaps counter-intuitively, compatible. The reason is that on its asset side the bank extends illiquid loans to borrowers with whom the bank has special and quasi-exclusive relations that leave room for mutual extraction of rents. The bank's position between its lenders who may demand liquidity and its borrowers who can extract rents is precarious but this very precariousness limits rent seeking and commits the bank to create liquidity.

Risky short-term debt is inferior to long-term debt in the term structure of corporate debt model of Diamond and He (2010). The firm modeled in Diamond and He has assets in place and the decision the equity holders need to make is whether to invest in the firm, given the risky distribution of the payoff of the investment and the amounts owed to the short- and long-term creditors. An investment by the equity holders enhances the values of the more senior claimants, sometime to render such investment unprofitable. This is the debt overhang problem which may lead the equity holders to forego socially desired investments. The problem may be more acute when the debt is short-term.

Similarly to the Diamond He model, this paper also considers the comparison of the investment incentives of short-term and long-term debt that will mature in the future. The



distinguishing feature of the present model is the presence of moral hazard: equity holders select the riskiness of the firm's assets after the initial debt has been issued. The need to roll over the short-term debt mitigates the moral hazard, thereby conferring additional value to short-term funding, to the extent that under some circumstances it dominates long-term debt financing.

Diamond (1991) considers an adverse selection model of a firm's choice of the term structure of its borrowing in which variation across borrower quality leads to variation across the optimal structures of debt maturity. The optimal maturity structure trades off a borrower's preference for short-term debt (due to private information about the future credit rating) against liquidity risk.

Rajan (1992) studies the borrower's choice of creditor between a bank and an arm's-length lender. The bank can lend either short- or long-term, whereas the arm's-length lender must lend long-term. The preference for bank debt maturity depends on the relative bargaining power of the bank and the borrower after the parties learn the true state of the project. Rajan's main focus is on the effect of lender's type on ex-ante borrower's choice of effort.

Huang and Ratnovski (2008) examine the trade-off between the bright side (efficient liquidation) and the dark side (inefficient liquidation) of banks' short-term financing, showing that the dark side dominates when the bank assets are more tradable, leading to more public signals and lower liquidation costs. However, as in Calomiris and Kahn (1991), the effect of short-term financing on ex ante risk-shifting incentives is not analyzed.

Repullo (2005) considers a moral hazard model that shares some features with this paper's model. However, his focus is not on the comparison between short-term and long-term debt, but on the effect on risk-shifting incentives of policies that an informed supervisor could implement at the outset of a crisis.

**Structure of paper** The paper is structured as follows. Section 2 presents the model. Sections 3 and 4 characterize equilibrium with long-term and short-term debt, respectively. Section 5 illustrates the results using numerical solutions for a simple parameterization of the model. Section 6 contains a few interesting extensions of the analysis, and Section 7

concludes. Proofs are in the Appendix.

## 2 The Basic Model

Consider an economy with two dates ( $t = 0, 1$ ), a risk-neutral bank, and a large number of risk-neutral (wholesale) *lenders* who expect a return normalized to zero.

At  $t = 0$  the bank can invest one unit of funds in a *risky asset* that yields a random payoff  $R$  at  $t = 1$ . The probability distribution of  $R$  is

$$R = \begin{cases} R_0 & \text{with probability } 1 - p, \\ R_1 & \text{with probability } p, \end{cases} \quad (1)$$

where  $R_0 = 0$ ,  $R(1) \geq 1$ , and  $p \in [0, 1]$ . Thus  $1 - p$  represents the riskiness of the bank's asset.

The bank chooses the parameter  $p \in [0, 1]$  at  $t = 0$  *after* it has raised the necessary funds. The payoff in the better outcome  $R_1 = R(p)$  is decreasing in  $p$ . Therefore a higher risk (lower  $p$ ) is associated with a higher success payoff  $R_1$ . The moral hazard emerges because the bank's shareholders prefer a higher  $p$  than its lenders.

The function  $R(p)$  is concave and satisfies  $R(1) + R'(1) \leq 0$ . These assumptions imply that the expected payoff of the risky asset,  $E(R) = pR(p)$ , reaches a maximum at  $p_{FB} \in (0, 1]$  that is characterized by the first-order condition:

$$(p_{FB}R(p_{FB}))' = 0. \quad (2)$$

To see this, notice that the first derivative of  $pR(p)$  with respect to  $p$  equals  $R(0) > 0$  for  $p = 0$  and  $R(1) + R'(1) \leq 0$  for  $p = 1$ , and the second derivative satisfies  $2R'(p) + pR''(p) < 0$ . Moreover, for the  $p_{FB}R(p_{FB}) \geq R(1) \geq 1$ .

The bank has no capital and can only fund its investment in the risky asset by borrowing from the risk-neutral lenders. But the bank can raise *more* than one unit of funds and pay out the excess  $D$  up-front as a dividend to the shareholders. The usefulness of this up-front dividend to ameliorate the bank's risk-shifting incentives emerges in some of the circumstances that give rise to the optimality of risky short-term debt.

**An example** The payoff function

$$R(p) = a(2 - p) \tag{3}$$

has the required properties and will be used to derive the numerical results in Section 5. Parameter  $a$  characterizes the profitability of the bank's investments. The derivative  $(pR(p))' = 2a(1 - p)$ , so  $p_{FB} = 1$ . Thus, the first-best would be a safe investment with  $R(p_{FB}) = a$ .

### 3 Long-term Debt

Suppose that the bank is funded with (long-term) debt that matures at  $t = 1$ , and let  $B$  denote the face value of the debt that lenders receive in exchange for  $1 + D$  funds provided at  $t = 0$ , where  $D \geq 0$  is the dividend paid up-front to the shareholders.

A *contract* with long-term debt between the bank and the lenders specifies the initial dividend  $D$  paid to the shareholders and the face value  $B$  of the debt payable to the lenders. Such contract determines the probability of success  $p$  chosen by the bank.

An *optimal contract* with long-term debt  $(D_{LT}, B_{LT}, p_{LT})$  is a solution to the following problem:

$$\max_{(D, B, p)} [D + p(R(p) - B)] \tag{4}$$

subject to the *incentive compatibility constraint*:

$$p_{LT} = \arg \max_p [p(R(p) - B)], \tag{5}$$

and the *participation constraint*:

$$pB \geq 1 + D. \tag{6}$$

The incentive compatibility constraint (5) characterizes the bank's choice of  $p$  given the promised repayment  $B$ ; the participation constraint (6) ensures that the lenders get the required expected return on their investment.

The solution to (5) is characterized by the first-order condition

$$(pR(p))' = B. \tag{7}$$

Since the left-hand side of (7) is decreasing in  $p$ , it follows that higher values of  $B$  are associated with lower values of  $p$ . This is the standard risk-shifting effect that obtains under debt finance. Moreover, using the characterization (2) of the first-best  $p_{FB}$ , it follows that  $p_{LT} < p_{FB}$ , that is the bank will take on more risk than if it were equity financed.

In the optimal contract the participation constraint (6) must be satisfied with equality. Otherwise, the dividend  $D$  could be increased, improving the shareholders' payoff function.

Moreover, in the optimal contract the initial dividend  $D_{LT} = 0$ . To see this, consider the effect on the bank's objective function of an increase in the face value  $B$  to fund an increase in the dividend  $D (= pB - 1)$ , that is

$$\frac{d}{dB} [p(R(p) - B) + (pB - 1)] = B \frac{dp}{dB} < 0,$$

which follows from the first-order condition (7) and the result  $dp/dB < 0$ . For this reason, a contract with long-term debt will henceforth be described by its face value  $B$  and the corresponding probability of success  $p$ .

Substituting the resulting participation constraint  $pB = 1$  into the first-order condition (7), and rearranging the resulting expression, gives the equation

$$H(p) = 1, \tag{8}$$

where

$$H(p) = p(pR(p))'. \tag{9}$$

Since  $(pR(p))'$  is positive for  $p < p_{FB}$ , it follows that the function  $H(p)$  is positive for  $0 < p < p_{FB}$ , and satisfies  $H(0) = H(p_{FB}) = 0$ .

The equation  $H(p) = 1$  may have no solution, a single solution or multiple solutions. In the first case, financing the bank with long-term debt will not be feasible: the bank's risk-shifting incentives are so strong that the lenders' participation constraint cannot be satisfied. In the second case, the single solution characterizes the optimal contract with long-term debt. And in the third case, the following result shows that the optimal contract is characterized by the solution with the highest probability of success.

**Proposition 1** *Financing the bank with long-term debt is feasible if the equation  $H(p) = 1$  has a solution, in which case  $(B_{LT}, p_{LT})$ , where  $B_{LT} = 1/p_{LT}$  and*

$$p_{LT} = \max\{p \in (0, p_{FB}) \mid H(p) = 1\}, \quad (10)$$

*will be the optimal contract with long-term debt.*

Summing up, it will be possible to fund the bank with long-term debt if the function  $H(p)$  takes values greater than or equal to 1 somewhere in the interval  $(0, p_{FB})$ . In this case, substituting the lenders' participation constraint into the bank's objective function yields the expected payoff

$$\pi_{LT} = p_{LT}R(p_{LT}) - 1. \quad (11)$$

This payoff will be compared with the one corresponding to the optimal contract with short-term debt below.

**An example (continued)** For the payoff function  $R(p) = a(2 - p)$ ,

$$H(p) = 2ap(1 - p). \quad (12)$$

Therefore,

$$p_{LT} = \frac{1}{2} \left( 1 + \sqrt{1 - \frac{2}{a}} \right) \quad (13)$$

Hence financing the bank with long-term debt requires  $a \geq 2$ . Figure 1 represents the function  $H(p)$  and the determination of  $p_{LT}$  and  $p_{FB}$  for  $a = 3.125$  (in which case  $p_{LT} = 0.8$ ). The success probability  $p_{LT}$  is increasing in parameter  $a$  (which characterizes the profitability of the bank's investments), with  $\lim_{a \rightarrow \infty} p_{LT} = p_{FB} = 1$ , and the face value of the long-term debt  $B_{LT}$  is decreasing in  $a$ , with  $\lim_{a \rightarrow \infty} B_{LT} = 1$ .

## 4 Short-term Debt

The introduction of an *interim date*  $t = 1/2$  facilitates the introduction of short-term (short-term) debt which matures at the interim date. Whether the short-term debt is rolled over

depends on information about the return of the bank's investment which is revealed at the rollover date. In particular, at  $t = 1/2$  the lenders (and possibly other, potential lenders) observe a *public signal*  $s \in \{s_0, s_1\}$  on the return of the bank's risky asset. Based on this signal, they decide whether to refinance the bank. If they do, final payoffs will be obtained at  $t = 1$ . If they do not, the bank will be liquidated at  $t = 1/2$  and the initial lenders will receive the liquidation value  $L$  of the bank's asset.

The signal  $s$  observed by the lenders at the interim date  $t = 1/2$  satisfies

$$\Pr(s_0 | R_0) = \Pr(s_1 | R_1) = q,$$

where parameter  $q \in [1/2, 1]$  describes the quality of the lenders' information. (In a more elaborate model with an additional parameter, it is possible that  $\Pr(s_0 | R_0) \neq \Pr(s_1 | R_1)$ , but then two parameters would describe the quality of the investors' information.) This information is only about whether the payoff  $R$  of the bank's risky asset will be low ( $R_0$ ) or high ( $R_1$ ), and not about the particular value  $R(p)$  taken by the high return. By Bayes' law

$$\Pr(R_1 | s_0) = \frac{\Pr(R_1) \Pr(s_0 | R_1)}{\Pr(s_0)} = \frac{p(1-q)}{p+q-2pq}, \quad (14)$$

and

$$\Pr(R_1 | s_1) = \frac{\Pr(R_1) \Pr(s_1 | R_1)}{\Pr(s_1)} = \frac{pq}{1-p-q+2pq}. \quad (15)$$

When  $q = 1/2$  the signal is uninformative because  $\Pr(R_1 | s_0) = \Pr(R_1 | s_1) = p$ . When  $q = 1$  the probabilities satisfy  $\Pr(R_1 | s_0) = 0$  and  $\Pr(R_1 | s_1) = 1$ , so the signal completely reveals whether the payoff  $R$  will be  $R_0$  or  $R_1$ . Since  $\Pr(R_1 | s_0) < p < \Pr(R_1 | s_1)$  for  $p < 1$  and  $q > 1/2$ , the states  $s_0$  and  $s_1$  will be called the bad and the good states, respectively.

The liquidation value  $L$  of the bank's asset at the interim date  $t = 1/2$  satisfies

$$L = \lambda E(R_1 | s),$$

where parameter  $\lambda \in [0, 1]$  is the recovery rate of the value of the investment. Thus,  $1 - \lambda$  captures the liquidation costs of the bank's asset. For any  $\lambda < 1$  liquidating the bank at  $t = 1/2$  will be inefficient.

Compared to the case of long-term debt, the model of short-term debt involves two additional parameters, namely the quality  $q$  of the lenders' interim information and the recovery rate  $\lambda$  of the bank's investment when it is liquidated early. The analysis below shows that short-term debt becomes more attractive when these parameters are close to 1, that is, when the quality of the interim information is high and the liquidation costs are low.

Suppose that the bank is funded with short-term debt that matures at the interim date  $t = 1/2$ , and let  $M$  denote the face value of the debt that lenders receive in exchange for  $1 + D$  funds provided at  $t = 0$ , where as before  $D \geq 0$  is the dividend paid up-front to the shareholders.

At  $t = 1/2$  the bank will try to issue new debt, payable at  $t = 1$ , in order to repay the initial lenders. The face value of this debt will naturally depend on the signal  $s$  observed by the lenders at the interim date. Let  $N_s$  denote the face value of the debt that lenders receive in exchange for  $M$  funds provided at  $t = 1/2$  when the signals is  $s$ .

The decision to roll over the initial debt depends on the corresponding conditional probability of success of the investment,  $\Pr(R_1 | s_0)$  or  $\Pr(R_1 | s_1)$ . As stated in (14) and (15), these posterior probabilities depend on the quality of the signal  $q$ , which is known, and the prior probability  $p$ , which is not. Hence, the interim lenders will have to decide on the basis of the value  $\hat{p}$  that they conjecture the bank chose at  $t = 0$ . In equilibrium  $\hat{p}$  must be equal to the true value of  $p$ . Let  $\widehat{\Pr}(R_1 | s_0)$  or  $\widehat{\Pr}(R_1 | s_1)$  denote the posterior probabilities corresponding to the prior probability  $\hat{p}$ .

At the interim date  $t = 1/2$ , the lenders will roll over the bank's initial debt  $M$  in state  $s$  if it satisfies

$$\widehat{E}(R_1 | s) \geq M,$$

that is, if the conjectured expected value of the bank's asset

$$\widehat{E}(R_1 | s) = \widehat{\Pr}(R_1 | s)R(\hat{p})$$

is at least equal to the face value  $M$  of the debt to be refinanced. In this case, there exists a face value  $N_s \leq R(\hat{p})$  of the new debt that satisfies the interim lenders' participation

constraint:

$$\widehat{\text{Pr}}(R_1 | s)N_s = M.$$

From here it follows that, if the initial debt is rolled over in state  $s$ , the face value of the interim debt will be

$$N_s = \frac{M}{\widehat{\text{Pr}}(R_1 | s)} \quad (16)$$

Paying a dividend at the interim date  $t = 1/2$  changes the face value  $N_i$  of the interim debt, but at this point  $p$  has already been chosen, so there is no benefit to paying an interim-date dividend. Therefore the interim lenders' participation constraint (16) is satisfied with equality. In contrast, paying a dividend at the initial date  $t = 0$  changes the face value  $M$  of the initial debt, and may have a positive effect on the bank's choice of  $p$ .

To describe the refinancing decision at  $t = 1/2$  it is convenient to introduce the following indicator function

$$I(x) = \begin{cases} 1 & \text{if } x \geq 0, \\ 0 & \text{otherwise,} \end{cases}$$

For each state  $s$ , variable  $x$  will denote the difference between the conjectured expected value of the bank's asset and the face value of the debt to be refinanced, that is

$$x = \widehat{E}(R_1 | s) - M.$$

The initial debt will be rolled over in state  $s$  if  $x \geq 0$ , so  $I(x) = 1$ . Otherwise,  $I(x) = 0$ .

The initial lenders' *participation constraint* may be written as

$$\varphi(\widehat{p}, M) = 1 + D, \quad (17)$$

where

$$\varphi(\widehat{p}, M) = \sum_{s=s_0, s_1} \widehat{\text{Pr}}(s) \left[ I(x)M + [1 - I(x)]\lambda\widehat{E}(R_1 | s) \right]. \quad (18)$$

When  $I(x) = 1$ , that is when  $\widehat{E}(R_1 | s) \geq M$ , the initial debt is rolled over and the initial investors are repaid  $M$ . When  $I(x) = 0$ , that is when  $\widehat{E}(R_1 | s) < M$ , the bank is liquidated and the initial lenders get the liquidation value  $L = \lambda\widehat{E}(R_1 | s)$ . The participation constraint (17) is written as an equality, because otherwise the dividend  $D$  could be increased, improving the shareholders' payoff function.



Taking into account the interim lenders' refinancing decision, the *bank's expected payoff* for given values of the dividend  $D$  and the face value of the initial debt  $M$  may be written as

$$\pi(D, M, p, \hat{p}) = D + \sum_{s=s_0, s_1} \Pr(s) I(x) \Pr(R_1 | s) \max \{R(p) - N_s, 0\}, \quad (19)$$

where  $N_s$  is given by (16). When  $I(x) = 1$ , that is when  $\hat{E}(R_1 | s) \geq M$ , the initial debt is rolled over and the shareholders get the dividend  $D$  plus the expected payoff  $\Pr(R_1 | s) \max \{R(p) - N_s, 0\}$ . When  $I(x) = 0$ , that is when  $\hat{E}(R_1 | s) < M$ , the bank is liquidated and the shareholders only get the dividend  $D$ .

A *contract* with short-term debt between the bank and its lenders specifies the initial dividend  $D$  paid to the shareholders and the face value  $M$  of the initial debt payable to the lenders. Such a contract determines the probability of success  $p$  chosen by the bank, the rollover decision at the interim date, and the face value of the interim debt  $N_s$  if the initial debt is rolled over in state  $s$ .

An *optimal contract* with short-term debt  $(D_{ST}, M_{ST}, p_{ST})$  is a solution to the following problem:

$$\max_{(D, M, p)} \pi(D, M, p, \hat{p}) \quad (20)$$

subject to the *incentive compatibility constraint*:

$$p_{ST} = \arg \max_p \pi(D, M, p, \hat{p}), \quad (21)$$

the initial lenders' *participation constraint* (18), and the *rational expectations constraint*:

$$\hat{p} = p_{ST}. \quad (22)$$

The incentive compatibility constraint (21) characterizes the bank's choice of  $p$  given the promised repayment  $M$  and the rollover decision implied by the lenders' conjecture  $\hat{p}$  of the value of  $p$  chosen by the bank. The participation constraint (17) ensures that the initial lenders get the required expected return on their investment. Finally, the rational expectations constraint requires that the conjectured  $\hat{p}$  equals the value  $p_{ST}$  chosen by the bank in the optimal contract.

There are two possible types of optimal contracts with short-term debt: one in which the initial debt is safe, in the sense that the initial lenders are always repaid, and another one in which the initial debt is risky, in the sense that the initial lenders are only repaid in the good state  $s_1$  (and the bank is liquidated in the bad state  $s_0$ ). (The equity holders will not support an equilibrium in which the bank is liquidated in both states.) The next subsections offer characterizations of these two types of contracts.

#### 4.1 Safe short-term debt

The easier case to analyze is that of safe short-term debt. This case is also less interesting because, as will be shown below, to every optimal short-term debt contract and its equilibrium success probability  $p$  there corresponds a long-term debt contract with the same success probability. The short-term safe contract is rolled over into another short-term debt contract. The face value of the latter is state-dependent and, regardless of the information revealed in the interim date, the second-period debt is *risky*. Thus, although every optimal short-term debt corresponds to an optimal long-term debt in terms of the choices of the success probability and the expected payoffs to the equity holders, the payoff distributions will vary across them. Moreover, under some parameter configurations, there are optimal long-term debt contracts with no corresponding short-term debt contracts.

With safe short-term debt, the initial lenders' participation constraint reduces to

$$\varphi(\hat{p}, M) = M = 1 + D,$$

and the bank's expected payoff function becomes

$$\begin{aligned} \pi(D, M, p, \hat{p}) &= D + \sum_{s=s_0, s_1} \Pr(s) \Pr(R_1 | s) [R(p) - N_s] \\ &= D + p(1 - q) \left[ R(p) - \frac{\hat{p} + q - 2\hat{p}q}{\hat{p}(1 - q)} M \right] + pq \left[ R(p) - \frac{1 - \hat{p} - q + 2\hat{p}q}{\hat{p}q} M \right] \\ &= D + pR(p) - pM \left[ \frac{\hat{p} + q - 2\hat{p}q}{\hat{p}} + \frac{1 - \hat{p} - q + 2\hat{p}q}{\hat{p}} \right] \\ &= D + p \left[ R(p) - \frac{M}{\hat{p}} \right], \end{aligned}$$

where  $N_s$  is from (16) and  $\Pr(R_1 | s_0)$  and  $\Pr(R_1 | s_1)$  are from (14) and (15), respectively.

From here it follows that, taking into account the participations constraint  $M = 1 + D$  and the rational expectations constraint  $\hat{p} = p$ , the first-order condition that characterizes the bank's optimal choice of  $p$  is

$$(pR(p))' = \frac{M}{p} = \frac{1 + D}{p},$$

which using the definition (9) of  $H(p)$  gives

$$H(p) = 1 + D.$$

For  $D = 0$  this is identical to the condition (8) that characterizes the optimal contract with long-term debt. And for the same incentive reasons as before, in the optimal safe short-term contract there should be no up-front dividend. Therefore the optimal contract with safe short-term debt has the form  $(1, p_{LT})$ .

However, for  $(1, p_{LT})$  to be an optimal contract with safe short-term debt it must be the case that the initial debt is refinanced in the bad state  $s_0$ , which gives the condition

$$E(R_1 | s_0) = \frac{p(1 - q)}{p + q - 2pq} R(p) \geq 1. \quad (23)$$

(Since  $\Pr(R_1 | s_1) > \Pr(R_1 | s_0)$ , this condition implies that the initial debt is also refinanced in the good state  $s_1$ .) For  $q = 1/2$  (uninformative signal) the condition becomes

$$pR(p) \geq 1,$$

which holds if long-term financing is feasible. For  $q = 1$  (perfectly informative signal) the condition is never satisfied: the left-hand-side of the inequality is zero.

Solving for  $q$  in (23) the condition that guarantees that the initial debt is refinanced in the bad state  $s_0$  becomes  $q \leq q(p)$ , where

$$q(p) = \frac{p(R(p) - 1)}{1 + p(R(p) - 2)}. \quad (24)$$

Note that the definition (24) implies that  $q(p_{LT}) > 1/2$  if and only if  $p_{LT}R(p_{LT}) > 1$ .

The main result pertaining to short-term safe debt is:

**Proposition 2** *Financing the bank with safe short-term debt is feasible if financing the bank with long term debt is feasible and if  $q \leq q(p_{LT})$ , where  $p_{LT}$  is defined in (10), in which case  $(1, p_{LT})$  will be the optimal contract with safe short-term debt.*

Proposition 2 shows that safe short-term debt is viable only if the quality  $q$  of the lenders' information is not too high. The intuition for this result is clear. When  $q$  is close to 1, observing the bad state  $s_0$  means that the conditional expected payoff of the bank's investment is close to zero, so the initial debt will not be refinanced. On the other hand, since the upper bound  $q(p_{LT})$  is strictly greater than  $1/2$ , when  $q$  is close to  $1/2$  funding the bank with safe short-term debt will be feasible (as long as funding it with long-term debt is).

Summing up, using safe short-term debt does not add anything relative to using long-term debt. Thus, the only possible role of short-term debt is when it is risky.

**An example (continued)** For the payoff function  $R(p) = a(2-p)$ , the optimal long-term contract is characterized by the probability of success  $p_{LT}$  in (13). This will also characterize the optimal contract with safe short-term debt if the quality of the lenders' information satisfies  $q \leq q(p_{LT})$ . Substituting (13) into  $q(p_{LT})$  and rearranging gives the condition:

$$q \leq q(a) = \frac{a\sqrt{a} + \sqrt{a-2}}{(1+a)\sqrt{a} + \sqrt{a-2}}.$$

Thus,  $q \leq 2/3$  for  $a = 2$ , the minimum value that ensures that the equation  $H(p) = 1$  has a solution. In this case, values of  $q$  higher than  $2/3$  imply that  $(1, p_{LT})$  will not be a feasible contract with safe short-term debt, because the initial debt will not be refinanced in the bad state  $s_0$ . It can be checked that the critical value  $q(a)$  is increasing in  $a$ , with  $\lim_{a \rightarrow \infty} q(a) = 1$ . So the higher profitability of the bank's investments the higher the range of values of  $q$  for which an optimal contract with safe short-term debt exists.

It should be noted that the short-term debt issued after the rollover of the initial debt is no longer safe. For example, for  $a = 3.125$  we have  $p_{LT} = 0.8$ , so for  $q \leq 11/12 = q(a)$  we conclude that  $(1, p_{LT})$  is an optimal contract with safe short-term debt. Taking  $q = 0.8 < 11/12$  and substituting  $M = 1$ ,  $p = 0.8$  and  $q = 0.8$  into (16) we get  $N_0 = [\Pr(R_1 | s_0)]^{-1} = 2$

and  $N_1 = [\Pr(R_1 | s_1)]^{-1} = 1.0625$ . Thus, in both states the bank pays a premium over the safe rate to cover the default risk.

[Rafa – What’s being gained by looking also at  $a = 3.125$ , in addition to  $a = 2$  or  $2.1$ ?]

## 4.2 Risky short-term debt

When the initial debt is risky, the initial lenders are only repaid in the good state  $s_1$ , and the bank is liquidated in the bad state  $s_0$ , in which case they get a fraction  $\lambda$  of their conjectured expected value of the bank’s asset  $\widehat{E}(R_1 | s_0)$ .

With risky short-term debt, the initial lenders’ participation constraint becomes

$$\varphi(\widehat{p}, M) = \widehat{\Pr}(s_0)\lambda\widehat{E}(R_1 | s_0) + \widehat{\Pr}(s_1)M = 1 + D.$$

Since

$$\widehat{\Pr}(s_0)\widehat{E}(R_1 | s_0) = \widehat{\Pr}(s_0)\widehat{\Pr}(R_1 | s_0)R(\widehat{p}) = (1 - q)\widehat{p}R(\widehat{p})$$

and  $\widehat{\Pr}(s_1) = 1 - \widehat{p} - q + 2\widehat{p}q$ , the constraint reduces to

$$\varphi(\widehat{p}, M) = \lambda(1 - q)\widehat{p}R(\widehat{p}) + (1 - \widehat{p} - q + 2\widehat{p}q)M = 1 + D. \quad (25)$$

The bank’s expected payoff function becomes

$$\begin{aligned} \pi(D, M, p, \widehat{p}) &= D + \Pr(s_1)\Pr(R_1 | s_1)[R(p) - N_1] \\ &= D + pq \left[ R(p) - \frac{1 - \widehat{p} - q + 2\widehat{p}q}{\widehat{p}q} M \right], \end{aligned} \quad (26)$$

where (16) defines  $N_s$  and the expression (15) gives  $\Pr(R_1 | s_1)$ .

From here (and from the rational expectations constraint  $\widehat{p} = p$ ) follows the first-order condition that characterizes the bank’s optimal choice of  $p$  is

$$(pR(p))' = \frac{1 - p - q + 2pq}{pq} M. \quad (27)$$

Solving for  $M$  in (25), substituting it into (26), and using the definition (9) of  $H(p)$  gives

$$H(p) = F(p, q, \lambda, D), \quad (28)$$

where

$$F(p, q, \lambda, D) = \frac{1 + D - \lambda(1 - q)pR(p)}{q}. \quad (29)$$

Since  $pR(p)$  is increasing and concave for  $p \leq p_{FB}$ , the function  $F(p, q, \lambda, D)$  is decreasing and convex in  $p$  over the same range.

For any given up-front dividend  $D$ , the equation  $H(p) = F(p, q, \lambda, D)$  may have no solution, a single solution, or multiple solutions. Suppose that  $p$  is a solution. Substituting  $M$  from (25) into (26) and taking into account the rational expectations constraint  $\hat{p} = p$ , the expected payoff of the bank's share holders is simply

$$\pi_{ST}(\lambda, q) = [q + \lambda(1 - q)]pR(p) - 1. \quad (30)$$

The expected payoff of the bank's equity holders is the gross payoff minus the unit initial investment which, in expectation, is repaid to the bank's creditors. With probability  $\Pr(s_1)$  the bank is not liquidated at  $t = 1/2$  and its value is  $\Pr(R_1 | s_1)R(p)$ , and with probability  $\Pr(s_0)$  the bank is liquidated at  $t = 1/2$  and its value is  $\lambda \Pr(R_1 | s_0)R(p)$ . But  $\Pr(R_1 | s_1) \Pr(s_1) = \Pr(s_1 | R_1) \Pr(R_1) = qp$  and  $\Pr(R_1 | s_0) \Pr(s_0) = \Pr(s_0 | R_1) \Pr(R_1) = (1 - q)p$ , which gives (30).

Since (30) is increasing in  $p$  (for  $p \leq p_{FB}$ ), it follows that in the case of multiple solutions the bank prefers the one with the highest probability of success. And since this solution is decreasing in  $D$  (given the shape of the function  $H(p)$  and the function  $F(p, q, \lambda, D)$  being increasing in  $D$ ), it also follows that the bank would prefer to set the initial dividend to zero.

However, for this to be an optimal contract with risky short-term debt, the initial debt cannot be rolled over in the bad state  $s_0$ , which gives the condition

$$E(R_1 | s_0) = \frac{p(1 - q)}{p + q - 2pq}R(p) \leq M. \quad (31)$$

This condition is written with a weak inequality, because when  $E(R_1 | s_0) = M$  the face value  $N_0$  of the new debt issued at  $t = 1/2$  equals  $R(p)$ , in which case the shareholders' stake is zero.

Substituting the lenders' participation constraint (25) into this expression gives

$$\frac{p(1-q)}{p+q-2pq}R(p) \leq \frac{1+D-\lambda(1-q)pR(p)}{1-p-q+2pq}, \quad (32)$$

which simplifies to

$$G(p, q, \lambda) = \left[ \frac{1}{p+q-2pq} - (1-\lambda) \right] p(1-q)R(p) \leq 1+D. \quad (33)$$

This condition may not be satisfied for  $D = 0$ , in which case it may still be possible to finance the bank with risky short-term debt by paying an up-front dividend  $D > 0$  and consequently raising the face value  $M$  of the initial debt so that it will not be rolled over in the bad state  $s_0$ .

The formal result is stated as follows.

**Proposition 3** *Financing the bank with risky short-term debt is feasible if the equation  $H(p) = F(p, q, \lambda, D)$  has a solution for some  $D \geq 0$  that also satisfies  $G(p, q, \lambda) \leq 1 + D$ , in which case the optimal contract with risky short-term debt is  $(D_{ST}, M_{ST}, p_{ST})$ , where*

$$p_{ST} = \max \{ p \in [0, p_{FB}] \mid H(p) = F(p, q, \lambda, D) \text{ and } G(p, q, \lambda) \leq 1 + D \}, \quad (34)$$

$D_{ST} = \max \{ G(p_{ST}, q, \lambda) - 1, 0 \}$ , and

$$M_{ST} = \frac{1 + D_{ST} - \lambda(1-q)p_{ST}R(p_{ST})}{1 - p_{ST} - q + 2p_{ST}q}. \quad (35)$$

The dependence of the solution on the parameters is denoted by  $(D_{ST}(q, \lambda), M_{ST}(q, \lambda), p_{ST}(q, \lambda))$ .

The comparative statics with respect to the recovery rate  $\lambda$  are clean:

**Proposition 4**

(i) *For a given signal quality  $q$ , there exists  $\lambda^*(q)$  such that:*

1. For  $\lambda \leq \lambda^*(q)$  the initial dividend  $D_{ST}(q, \lambda) = 0$  and for  $\lambda < \lambda^*(q)$ ,  $p_{ST}(\lambda)$  is strictly increasing.

2. For  $\lambda > \lambda^*(q)$  the initial dividend  $D_{ST}(q, \lambda) > 0$  and for  $\lambda \geq \lambda^*(q)$ ,  $p_{ST}(\lambda)$  is constant.

(ii) The profit function increases in the recovery rate  $\lambda$ ,

(iii) The face value of the initial debt,  $M_{ST}$ , decreases with the recovery rate  $\lambda$ .

At this point it will be nice to derive comparative statics with respect to  $q$ . For the region where  $D = 0$ , the first order condition (28) can be differentiated with respect to  $q$  and  $\lambda$  to obtain:

$$\{[p_{ST}(p_{ST}R(p_{ST}))]' + \frac{1-q}{q}\lambda(p_{ST}R(p_{ST}))\}' \frac{\partial p_{ST}}{\partial q} = \frac{\lambda p_{ST}R(p_{ST}) - 1}{q^2} \quad (36)$$

$$\{[p_{ST}(p_{ST}R(p_{ST}))]' + \frac{1-q}{q}\lambda(p_{ST}R(p_{ST}))\}' \frac{\partial p_{ST}}{\partial \lambda} = \frac{-\lambda(1-q)pR(p)}{q} \quad (37)$$

Notice that the right hand side of (37) is negative and  $\partial p_{ST}/\partial \lambda > 0$ . Since the term that multiplies the partial derivatives of  $p_{ST}$  is the same across the equations, and it is negative in (37), it follows that the sign of  $\partial p_{ST}/\partial q$  is opposite the sign of  $\lambda p_{ST}R(p_{ST}) - 1$ . Moreover,  $\partial p_{ST}/\partial q = 0$  if  $\lambda p_{ST}R(p_{ST}) = 1$ .

Proposition 3 shows that the feasibility of funding the bank with risky short-term debt depends in a somewhat complex manner on the quality  $q$  of the lenders' information and on the recovery rate  $\lambda$  of the value of the investment when the bank's initial debt is not rolled over. Interestingly, the optimal contract may involve paying the bank an initial dividend  $D > 0$ . Characterizing the conditions under which this will happen is not easy, but nevertheless one can derive some analytical results.

For example, when the quality  $q$  of the lenders' information is sufficiently high, the constraint  $G(p, q, \lambda) \leq 1 + D$  will always be satisfied (since  $\lim_{q \rightarrow 0} G(p, q, \lambda) = 0$ ), and hence the optimal contract with risky short-term debt has no up-front dividend. In the limit case of a perfectly informative signal ( $q = 1$ ), since  $H(p) = F(p, q, \lambda, 0) = 1$ , it follows that the optimal contract with risky short-term debt is equivalent to the optimal long-term contract. The intuition for this is clear. When  $q = 1$ , observing the bad signal  $s_0$  and liquidating the bank at  $t = 1/2$  yields the same payoffs as those associated with getting the bad return  $R_0 = 0$  at  $t = 1$ . Similarly, when the signal is uninformative ( $q = 0$ ), the first period debt is safe, and the second period debt is the same as the long-term debt. There is no advantage to short-term debt.



Summing up, Proposition 3 states the conditions under which it will be possible to fund the bank with risky short-term debt. The corresponding expected payoff will be written as

$$\pi_{ST} = [q + \lambda(1 - q)] p_{ST} R(p_{ST}) - 1. \quad (38)$$

We would like to compare the conditions under which financing the bank with either long-term or risky short-term debt are feasible, and when both are so, to compare  $\pi_{LT}$  defined in (11) with  $\pi_{ST}$  defined in (38) in order to assess which one will dominate. Since this is not easy to do analytically, in Section 5 we resort to numerical solutions.

**An example (continued)** For the payoff function  $R(p) = a(2 - p)$ , the condition  $H(p) = F(p, q, \lambda, D)$  that characterizes the values of  $p$  and  $D$  that satisfy the bank's incentive compatibility constraint and the lenders' participation constraint becomes:

$$D = -a[2q + \lambda(1 - q)]p^2 + 2a[q + \lambda(1 - q)]p - 1, \quad (39)$$

and the condition  $G(p, q, \lambda) \leq 1 + D$  that characterizes the the values of  $p$  and  $D$  for which the initial debt will not be rolled over in the bad state  $s_0$  becomes:

$$D \geq \left[ \frac{1}{p + q - 2pq} - (1 - \lambda) \right] a(1 - q)p(2 - p) - 1. \quad (40)$$

Figure 2 plots these functions for  $a = 3.125$ ,  $q = 0.8$ , and  $\lambda = 0.8$ . The probability of success  $p_{ST}$  in the optimal contract with risky short-term debt is the highest  $p$  on the parabola  $H(p) = F(p, q, \lambda, D)$  that satisfies the condition  $G(p, q, \lambda) \leq 1 + D$ , which gives  $p_{ST} = 0.72$  and  $D_{ST} = 0.46$ .

### 4.3 A Mix of Risky Short- and Long-Term Debt

This subsection applies a three step argument to demonstrate that when risky short-term debt dominates long-term debt, a mix of the two is not superior to just risky short-term debt. The first step shows that if the initial dividend  $D$  is positive then the long-term debt is zero; the second shows that if the initial dividend is zero then the choice of the success

probability is unaffected by the face value of the long-term debt. In the first two steps it is assumed that the short-term debt is risky. The third step demonstrates that the insolvency constraint tightens as the face value of the long-term debt increases. Therefore, to the extent that risky short-term debt is desirable, nothing is gained by mixing it with long-term debt.

The modified model entails the initial sale of two types of debt, one (short-term), with face value  $M$ , which matures after the public signal is observed, and another (long-term), with face value  $B$ , which matures after the project's proceeds are realized. The excess of the proceeds of the bonds' sale above one (the amount required to pursue the project),  $D$ , is distributed to the shareholders as soon as it is raised. When the short-term debt matures it is refinanced if new creditors are willing to lend  $M$  to the firm. This new short term debt matures at the same time as the outstanding long-term debt with face value  $B$  and is junior to it. If new creditors are not willing to lend  $M$  to the firm, the firm liquidates and the proceeds go to pay the original short-term creditors; to the extent the liquidation value  $L$  exceeds the face value of the initial short-term debt  $M$ , the rest of the liquidation proceeds go to the outstanding long-term creditors.

Initially the probability  $p$  is unknown, but the creditors conjecture it to be  $\hat{p}$ ; moreover, as the equity holders make their choices, they too take into account the same conjectured probability. In equilibrium, the probability they choose  $p$  equals  $\hat{p}$ .

If the initial short-term debt is indeed risky, in state  $s_0$  (which occurs with probability  $p + q - 2pq$ ) it pays  $\min\{L, M\}$ . The liquidation value  $L = \lambda E(R_1 | s)$ . In state  $s_1$  (which occurs with probability  $1 - p - q + 2pq$ ) it pays  $M$  because the shareholders issue a new short-term debt with face value  $N_1 = M / \Pr(R_1 | s_1) = (1 - p - q + 2pq) M / pq$ .

The long-term debt pays the residual of the liquidation value,  $[L - M]^+$  in state  $s_0$ . If the signal is good (i.e., in state  $s_1$ ) and the project is successful the long-term debt pays  $B$ ; this happens with probability  $pq$ . The long-term debt pays nothing if, following a good signal, the project fails; this happens with probability  $1 - p - q + pq$ .

For the short-term debt to be indeed risky, i.e., for the shareholders to be unable to refinance it, the expected future payoff in excess of long-term debt repayment,  $[R(\hat{p}) -$

$B]/\widehat{\Pr}\{R_1|s_0\}$ , must not exceed the short-term debt's face value, i.e.,

$$\frac{\widehat{p}(1-q)[R(\widehat{p})-B]}{\widehat{p}+q-2\widehat{p}q} \leq M. \quad (41)$$

(The reference to the conjectured probability is to emphasize the vantage point of the initial decision makers – the equity holders and the potential creditors.)

The participation constraint requires that the sum of the expected value of the short-term debt (i.e.,  $(1-\widehat{p}-q+2\widehat{p}q)M + (\widehat{p}+q-2\widehat{p}q)\min\{M, L\}$ ) and that of the long-term debt (i.e.,  $\widehat{p}qB + [L-M]^+(\widehat{p}+q-2\widehat{p}q)$ ) exceed the initial investment plus the initial dividend,

$$(1-\widehat{p}-q+2\widehat{p}q)M + (\widehat{p}+q-2\widehat{p}q)\min\{M, \widehat{L}\} + \widehat{p}qB + [\widehat{L}-M]^+(\widehat{p}+q-2\widehat{p}q) \geq 1+D$$

Which simplifies to

$$(1-\widehat{p}-q+2\widehat{p}q)M + \widehat{p}qB + \widehat{L}(\widehat{p}+q-2\widehat{p}q) \geq 1+D \quad (42)$$

The shareholders choose the face values of the two debt types,  $B$  and  $M$ , the initial dividend  $D$ , and shortly thereafter they choose the success probability  $p$  so as to

$$\max\left\{pq[R(p)-B - \frac{M(1-\widehat{p}-q+2\widehat{p}q)}{\widehat{p}q}] + D\right\} \quad (43)$$

subject to (41), (42),

$$B, D, M, \geq 0 \quad (44)$$

and the equilibrium constraint,

$$p = \widehat{p}. \quad (45)$$

Having chosen the two debt types,  $B$  and  $M$  and the initial dividend  $D$ , the first order condition associated with the choice of  $p$  is

$$(pR(p))' = B + \frac{M(1-p-q+2pq)}{pq}. \quad (46)$$

Denote the optimal solution to the problem by  $B_M, D_M, M_M, p_M$ .

**Lemma 5** (i) The participation constraint (42) obtains as an equality. (ii) If the insolvency constraint (41) is strict and if the initial dividend  $D_M > 0$  then the long-term debt  $B_M = 0$ .

Since with a positive initial dividend  $D$  there is no role to a mix of risky short-term debt and long-term debt, it remains to explore the implications of the initial dividend being zero. To this end extract  $B = 1 - [L(p+q-2pq) - (1-p-q+2pq)M]/pq$  from (42) and, applying (45) substitute  $B$  into the right hand side of the first order condition (46) to obtain

$$(pR(p))' = \frac{1 - L(p+q-2pq)}{pq} \quad (47)$$

which is the same as (28) with  $D = 0$ . Thus, a positive face value of the long term debt  $B$  offers no improvement in the choice of the success probability  $p$ .

Finally, remains the question of whether a positive  $B$  and a correspondingly lower  $M$  can increase the set of success probabilities for which the state  $s_0$ -insolvency constraint (41) holds. An equality of the participation constraint (33) implies that an increase of  $B$  by  $\delta$  must be accompanied by a decrease of  $M$  by  $\delta pq/(1-p-q+2pq)$ . These changes decrease the left and right hand sides of the state  $s_0$ -insolvency constraint (41) by  $\delta p(1-q)/p+q-2pq$  and  $\delta pq/(1-p-q+2pq)$  respectively. Since  $q \geq 1/2$ , these changes decrease the left hand side by a greater amount than they decrease the right hand side, thereby making the state  $s_0$ -insolvency constraint (41) tighter. Thus, a positive  $B$  does not increase the set of success probabilities for which the insolvency constraint holds.

## 5 Numerical Results

This section poses the following questions: (i) under what conditions will long-term and risky short-term debt be feasible? and (ii) under what conditions will long-term debt be dominated by risky short-term debt? To answer them we resort to numerical solutions for

the simple parameterization of the model that we have introduced in our previous example, namely  $R(p) = a(2 - p)$ , where parameter  $a$  characterizes the profitability of the bank's investments. As noted in Section 2, for this function we have  $p_{FB} = 1$ , so first-best would be a safe investment with  $R(p_{FB}) = a$ . Hence investments with  $a \geq 1$  would be funded in a world without moral hazard.

We have shown in Section 3 that for this payoff function the optimal contract with long-term debt is  $(B_{LT}, p_{LT})$ , where  $B_{LT} = 1/p_{LT}$  and  $p_{LT}$  is given by (13). Hence financing the bank with long-term debt requires  $a \geq 2$ . This means that the moral hazard problem prevents financing with long-term debt investments with  $1 \leq a < 2$ .

We next consider whether we can expand the range of values of  $a$  for which financing the bank with risky short-term debt is feasible. To confirm that this is the case, suppose that  $a$  is slightly below 2, so the equation  $H(p) = 0$  that characterizes the optimal contract with long-term debt has no solution, and consider reducing the value of  $q$  slightly below 1. We have seen that for  $q = 1$  the equation  $H(p) = F(p, q, \lambda, D)$  has no solution for any  $D \geq 0$  (and it reduces to  $H(p) = 1$  for  $D = 0$ ). What happens with this equation when we reduce  $q$  below 1? Differentiating the right hand side of (39) with respect to  $q$  we get  $ap[2(1 - \lambda) - (2 - \lambda)p]$ , which is negative for  $\lambda$  close to 1. Therefore, in this case a reduction in  $q$  shifts up the concave parabola in the right hand side of (39) in such a way that it may intersect the horizontal axis. Moreover, since for  $q$  close to 1 the initial debt will not be rolled over in the bad state  $s_0$ , there will be an optimal contract with risky short-term debt.

The preceding argument shows that for  $q < 1$  it may be possible to fund the bank with risky short-term debt for a range of values of  $a$  below 2. Solving for the optimal contract for different values of the three parameters  $a$ ,  $\lambda$ , and  $q$ , we find that the minimum feasible value of  $a$  is 1.65 (with  $\lambda = 1$  and  $q = 0.63$ ). We conclude that using risky short-term debt significantly expands the range of values of  $a$  for which the bank can be financed. In other words, risky short-term debt ameliorates the moral hazard problem, but obviously it does not solve it since investments with  $1 \leq a < 1.64$  will still not be funded.

As noted in Section 4, the optimal contract with risky short-term debt may involve paying an initial dividend  $D > 0$ . Figure 3 shows for  $a = 1.9$  the range of values of the recovery rate

$\lambda \in [0, 1]$  and the quality of the lenders' information  $q \in [1/2, 1]$  for which funding the bank with risky short-term debt is feasible (Regions I and II) and for which the optimal contract is characterized by a positive up-front dividend (Region II). Notice that these regions are such that the bank's liquidation costs are pretty low (a relatively high value of  $\lambda$ ) and the lenders' information is quite noisy (a relatively low value of  $q$ ). Also, notice that up-front dividends are paid when the lenders' information is very noisy.

It remains to consider what happens when both long-term and risky short-term debt are feasible, that is when  $a \geq 2$ . Figure 4 shows for  $a = 2.1$  the range of values of the recovery rate  $\lambda \in [0, 1]$  and the quality of the lenders' information  $q \in [1/2, 1]$  for which risky short-term debt dominates long-term debt (Regions I and II), long-term debt dominates risky short-term debt (Region III), and for which long-term debt is the only way to finance the bank (Region IV). As before, in the green region corresponds to the case in which the optimal contract is characterized by a positive up-front dividend. Hence, risky short-term debt is optimal for high values of  $\lambda$  and a fairly wide range of values of  $q$ .

We can summarize these results as follows. First, risky short-term debt may be the only to secure funding, which happens when the profitability of the investment  $a$  is low and the quality  $q$  of the lenders' information is relatively low. Second, risky short-term debt may dominate long-term debt, when the latter is feasible, which happens when the markets for the resale of banks' assets are very efficient (high  $\lambda$ ). Third, risky short-term debt may involve paying an initial dividend, which happens when the quality of the lenders' information is especially noisy (relatively low  $q$ ). Finally, it should be noted that risky short-term debt may be optimal, even if it entails inefficient liquidation with positive probability, because it ameliorates the bank's risk-shifting incentives.

## 6 Extensions

[To be written]

## 7 Concluding Remarks

The cost of having issuing a short-term debt against long-term assets is that it will not be renewed, leaving the assets unfunded and therefore forcing liquidation, which entails deadweight loss. Much of the banking literature studies failure to renew the short-term debt because of needs of the lenders or their (possibly false) perceptions of soundness of the assets. This work analyses the benefit of short-term debt: it mitigates equity holders' temptation to select risky assets.

For short-term debt to be an effective incentive device it must be risky. To be risky, the face value of the debt cannot be too low; with too low a face value it will not default. If the face value of the first period debt is sufficiently high, then the face value of the second period debt will also have to be high, which implies that the shareholders cannot collect too big a portion of the project's final payoff. To satisfy this latter condition, it may help to inflate the debt in the first place by borrowing more than the amount necessary to invest and paying the surplus to the shareholders up-front as a dividend from the proceeds of the first period short-term debt.

## 8 Appendix

**Proof of Proposition 1** Suppose that there exist  $p_1$  and  $p_2$ , with  $p_1 < p_2$ , such that  $H(p_1) = H(p_2) = 1$ . The contract  $B_2 = 1/p_2$  dominates the contract  $B_1 = 1/p_1$ , because the function  $pR(p)$  is increasing in  $p$  in the interval  $(0, p_{FB})$ , implying that the corresponding bank payoffs satisfy

$$p_1 (R(p_1) - B_1) < p_2 (R(p_2) - B_2).$$

Hence if equation (8) has multiple solutions, the optimal contract with long-term debt is characterized by the one with the highest probability of success.  $\square$

**Proof of Proposition 2** By Proposition 1, if financing the bank with long-term debt is feasible, then the optimal contract with long-term debt is characterized by highest solution  $p_{LT}$  to the equation  $H(p) = 1$ . By our previous discussion, this solution will also characterize

the optimal contract with safe short-term debt if  $q \leq q(p_{LT})$ . If this condition is violated, no other solution to the equation  $H(p) = 1$  will satisfy it, because  $\frac{dq(p)}{dp} = \frac{(pR(p))' + pR(p) - 1}{[1 + p(R(p) - 2)]^2} > 0$ . Moreover, paying an up-front dividend  $D$  will not help with this constraint, since the highest solution to the equation  $H(p) = 1 + D$  is decreasing in  $D$ .  $\square$

**Proof of Proposition 3** The condition  $H(p) = F(p, q, \lambda, D)$  characterizes the values of  $p$  and  $D$  that satisfy the bank's incentive compatibility constraint and the lenders' participation constraint. The condition  $G(p, q, \lambda) \leq 1 + D$  characterizes the the values of  $p$  and  $D$  for which the initial debt will not be rolled over in the bad state  $s_0$ . The set of feasible contracts with risky short-term debt are those that satisfy both of these conditions.

Since the bank's expected payoff (30) is increasing in  $p$ , the optimal contract will be characterized by the highest value of  $p$  that satisfies these two conditions, which gives (30). The optimal value of the initial dividend  $D$  will be zero when  $G(p, q, \lambda) \leq 1$  for the highest value of  $p$  that satisfies  $H(p) = F(p, q, \lambda, 0)$ , and it will be  $G(p, q, \lambda) - 1$  when this is not the case. Note that when the dividend  $D > 0$ , it follows that  $G(p, q, \lambda) = 1 + D$ ; otherwise it would be possible to find a feasible contract with a higher  $p$ . Finally, the face value  $M_{ST}$  of the initial debt in the optimal contract is obtained by solving for  $M$  in the participation constraint (25).  $\square$

**Proof of Proposition 4** The proof is done in a sequence of steps.

**Step 1** Useful notation.

The dependence of the solution on the parameters is denoted by  $(D_{ST}(q, \lambda), M_{ST}(q, \lambda), p_{ST}(q, \lambda))$ . Note that  $p_{ST}(q, \lambda) < p_{FB}$ ; otherwise, equation (28) implies that  $F(p_{ST}(q, \lambda), q, \lambda, D_{ST}(q, \lambda)) = 0$  which contradicts equation (32).

For every  $p, q, \lambda$  equation (28) has a unique solution in  $D$ . Denote the solution as  $D(p, q, \lambda)$ , i.e. it satisfies (after some straightforward algebraic manipulation):

$$D(p, q, \lambda) = qp(pR(p))' + \lambda p(1 - q)R(p) - 1 \quad (48)$$

The function  $D(p, q, \lambda)$  is continuous and differentiable in all its arguments.



Let  $\mathbf{A}(q, \lambda) = \{p \in [0, p_{FB}], \text{ s.t. } D(p, q, \lambda) \geq 0, G(p, q, \lambda) \leq 1 + D(p, q, \lambda)\}$ . The set  $\mathbf{A}(q, \lambda)$  is either empty or a compact set. If this set is non empty then it is connected and thus a closed subinterval of  $[0, 1]$ .

Proposition 4 can be restated: if  $\mathbf{A}(q, \lambda) \neq \emptyset$  then risky short-term debt is feasible and

$$\begin{aligned} p_{ST}(q, \lambda) &= \max(\mathbf{A}(q, \lambda)), \\ D_{ST}(q, \lambda) &= D(p_{ST}(q, \lambda), q, \lambda). \end{aligned}$$

Now define the following set:

$$\mathbb{A}^\lambda(q) = \{\lambda \in [0, 1] \text{ s.t. } \mathbf{A}(q, \lambda) \neq \emptyset\}.$$

For later use in this proof let us state the following relationship, for  $\lambda_1, \lambda_2 \geq 0$ ,

$$D(p, q, \lambda_1) = D(p, q, \lambda_2) + (\lambda_1 - \lambda_2)p(1 - q)R(p) \quad (49)$$

Finally the function  $G(p, q, \lambda)$  is strictly increasing in both  $p \in (0, p_{FB})$  and  $\lambda$ . The intuition is that as  $p, \lambda$  decrease, conditional on the bad signal expected profits increase and it is more difficult to induce default at that state.

**Step 2** If  $D_{ST}(q, \lambda) > 0$  then  $G(p_{ST}(q, \lambda), q, \lambda) = 1 + D_{ST}(q, \lambda)$ .

By definition  $D(p_{ST}(q, \lambda), q, \lambda) = D_{ST}(q, \lambda) > 0$ . It is easy to observe that always  $p_{ST}(q, \lambda) < p_{FB}$ <sup>1</sup> and then if the lemma were not true, by continuity there would be a neighbourhood of  $p_{ST}(q, \lambda)$  such that for all  $p$ ,  $D(p, q, \lambda) > 0$  and  $G(p, q, \lambda) < 1 + D(p, q, \lambda)$ . If we take a  $p > p_{ST}(q, \lambda)$  in this neighbourhood it would satisfy  $p \in \mathbf{A}(q, \lambda)$  which contradicts maximality of  $p_{ST}(q, \lambda)$ .

**Step 3**  $\mathbb{A}^\lambda(q) = [\lambda_{\min}(q), 1]$  and  $p_{ST}(\lambda)$  is non-decreasing in  $\lambda$ .

It suffices to show that if  $\lambda_1 > \lambda_2$  then  $\mathbf{A}(q, \lambda_2) \subseteq \mathbf{A}(q, \lambda_1)$ .

Let us suppose that  $\mathbf{A}(q, \lambda_2) \neq \emptyset$  and let  $p \in \mathbf{A}(q, \lambda_2)$ . Using equation (49) we have

$$D(p, q, \lambda_1) = D(p, q, \lambda_2) + (\lambda_1 - \lambda_2)p(1 - q)R(p) > D(p, q, \lambda_2) \geq 0.$$

---

<sup>1</sup>If  $p_{ST}(q, \lambda) = p_{FB}$  then equation (28) implies  $F(p_{ST}(q, \lambda), q, \lambda, D_{ST}(q, \lambda)) = 0$  and equation (32) cannot be satisfied.

It is straightforward to check that  $G(p, q, \lambda_1) \leq 1 + D(p, q, \lambda_1)$  is equivalent to  $G(p, q, \lambda_2) \leq 1 + D(p, q, \lambda_2)$  and thus  $p \in \mathbf{A}(q, \lambda_1)$ .

Let us now define  $\lambda^*(q) = \max\{\lambda \in \mathbb{A}^\lambda(q) \text{ s.t. } D_{ST}(q, \lambda) = 0\}$ .

**Step 4** For  $\lambda \leq \lambda^*(q)$  we have  $D_{ST}(q, \lambda) = 0$  and for  $\lambda > \lambda^*(q)$  we have  $D_{ST}(q, \lambda) > 0$

The last part of the statement is consequence of the definition of  $\lambda^*(q)$ .

Since the set  $\{\lambda \in \mathbb{A}^\lambda(q) \text{ s.t. } D_{ST}(q, \lambda) = 0\}$  is closed  $D_{ST}(q, \lambda^*(q)) = 0$ . Let us suppose that there exists  $\lambda_1 < \lambda^*(q)$  and  $D_{ST}(q, \lambda_1) > 0$  then Step 2 implies that  $G(p_{ST}(q, \lambda_1), q, \lambda_1) = 1 + D_{ST}(q, \lambda_1)$ . Now it is easy to get a contradiction using  $p_{ST}(\lambda_1) \leq p_{ST}(\bar{\lambda})$  (Step 3),  $G$  is increasing in  $p$  and  $\lambda$ , and that  $D_{ST}(q, \lambda_1) > 0 = D_{ST}(q, \lambda^*(q))$ .

**Step 5** For  $\lambda_{\min}(q) \leq \lambda_1 < \lambda_2 \leq \lambda^*(q)$  we have  $p_{ST}(q, \lambda_1) < p_{ST}(q, \lambda_2)$

We know from Step 1 that  $p_{ST}(q, \lambda_1) \leq p_{ST}(q, \lambda_2)$ . Let us suppose that  $p_{ST}(q, \lambda_1) = p_{ST}(q, \lambda_2)$ . Then using that  $D_{ST}(q, \lambda_1) = D_{ST}(q, \lambda_2) = 0$  (Step 4) by construction we would have:

$$\begin{aligned} H(p_{ST}(q, \lambda_2)) &= H(p_{ST}(q, \lambda_1)) = F(p_{ST}(q, \lambda_1), q, \lambda_1, 0) > \\ &> F(p_{ST}(q, \lambda_1), q, \lambda_2, 0) = F(p_{ST}(q, \lambda_2), q, \lambda_2, 0) = H(p_{ST}(q, \lambda_2)) \end{aligned}$$

where in the inequality we have used that trivially  $p_{ST}(\lambda_1) > 0$  and  $\lambda_1 < \lambda_2$ . The previous inequality is a contradiction.

**Step 6** For  $\lambda_1 > \lambda^*(q)$  we have  $p_{ST}(q, \lambda_1) = p_{ST}(q, \lambda^*(q))$

Let us assume that  $\lambda^*(q) < 1$ , otherwise there is nothing to prove.

Because of Step 2 for all  $\lambda > \lambda^*(q)$ ,  $D(p_{ST}(q, \lambda), q, \lambda) > 0$  and thus by Step 2  $G(p_{ST}(q, \lambda), q, \lambda) = 1 + D(p_{ST}(q, \lambda), q, \lambda)$ .

A continuity argument then implies:

$$G(p_{ST}(q, \lambda^*(q)), q, \lambda^*(q)) = 1 + D(p_{ST}(q, \lambda^*(q)), q, \lambda^*(q)) = 1$$

Let us assume that there exists  $\lambda_1 > \lambda^*(q)$  such that  $p_{ST}(q, \lambda_1) > p_{ST}(q, \lambda^*(q))$ . Then  $G(p_{ST}(q, \lambda_1), q, \lambda_1) = 1 + D(p_{ST}(q, \lambda_1), q, \lambda_1)$  and it is straightforward to check that therefore:

$$G(p_{ST}(q, \lambda_1), q, \lambda^*(q)) = 1 + D(p_{ST}(q, \lambda_1), q, \lambda^*(q)) \quad (50)$$

Let us distinguish 2 cases:

i)  $D(p_{ST}(q, \lambda_1), q, \lambda^*(q)) \geq 0$  : We have  $p_{ST}(q, \lambda_1) > p_{ST}(q, \lambda^*(q))$  and equation above implies  $p_{ST}(q, \lambda_1) \in \mathbf{A}(q, \lambda^*(q))$  which contradicts the fact that  $p_{ST}(q, \lambda^*(q)) = \max(\mathbf{A}(q, \lambda^*(q)))$

ii)  $D(p_{ST}(q, \lambda_1), q, \lambda^*(q)) < 0$  : then since  $D(p_{ST}(q, \lambda_1), q, \lambda_1) > 0$  (Step 4) there exists  $\lambda \in (\lambda^*(q), \lambda_1)$  such that  $D(p_{ST}(q, \lambda_1), q, \lambda) = 0$ . As in equation (50) we have:

$$G(p_{ST}(q, \lambda_1), q, \lambda) = 1 + D(p_{ST}(q, \lambda_1), q, \lambda) = 1$$

but then since  $p_{ST}(q, \lambda_1) > p_{ST}(q, \lambda^*(q))$ ,  $\lambda > \lambda^*(q)$  and  $G$  is increasing in  $p$  and  $\lambda$  :

$$1 = G(p_{ST}(q, \lambda^*(q)), q, \lambda^*(q)) < G(p_{ST}(q, \lambda_1), q, \lambda) = 1$$

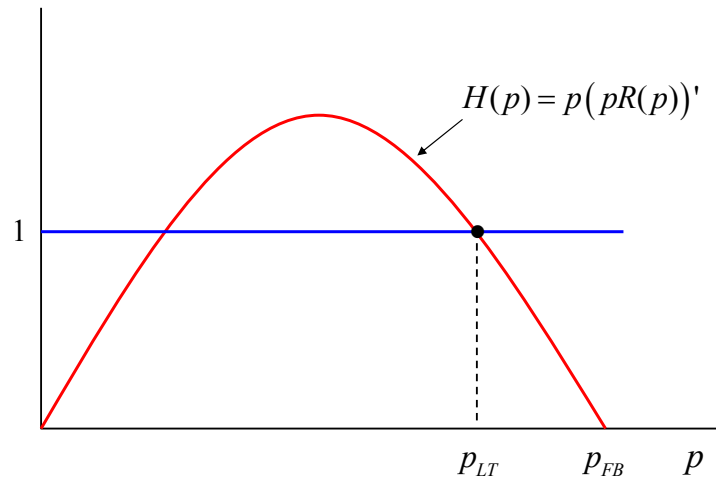
which is a contradiction.  $\square$

**Proof of Lemma 5** (i) Suppose otherwise and increase  $D_M$  to improve the objective value while leaving the other variables intact. (ii) Suppose otherwise and reduce  $D_M$  and  $B_M$  to  $D' = D_M - \delta$  and  $B' = B_M - \delta p_M q$  respectively without violating (41) and while maintaining (42). The change in  $B$  and the first order condition (46) imply that as a result the chosen  $p$  increases which increases the objective value.  $\square$

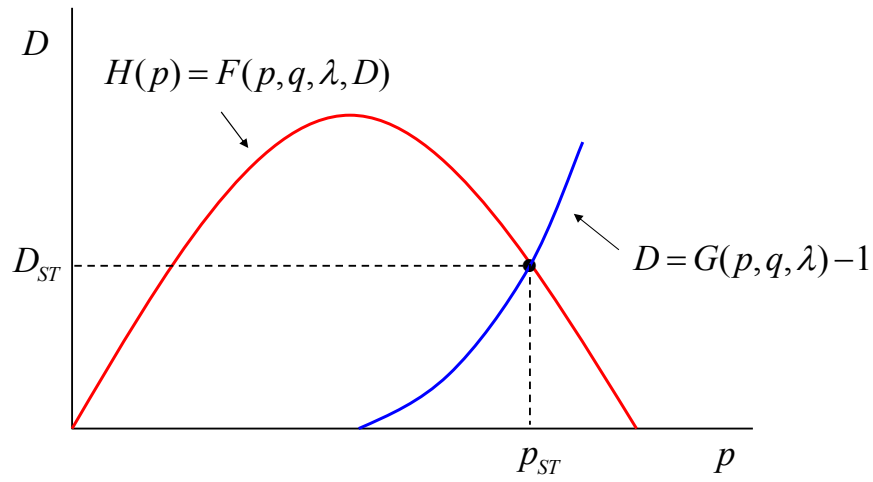
## References

- Allen, F., and D. Gale (2000): *Comparing Financial Systems*, Cambridge, MA: MIT Press.
- Calomiris, C., and C. Kahn (1991): "The Role of Demandable Debt in Structuring Optimal Banking Arrangements," *American Economic Review*, 81, 497-513.
- Diamond, D. (1991), "Debt Maturity Structure and Liquidity Risk," *Quarterly Journal of Economics*, 106, 709-737.
- Diamond, D. W., and P. H. Dybvig (1983): "Bank Runs, Deposit Insurance, and Liquidity," *Journal of Political Economy*, 91, 401-419.
- Diamond, D. W., and R. G. Rajan (2001), "Liquidity Risk, Liquidity Creation and Financial Fragility: A Theory of Banking," *Journal of Political Economy*, 109, 287-327.

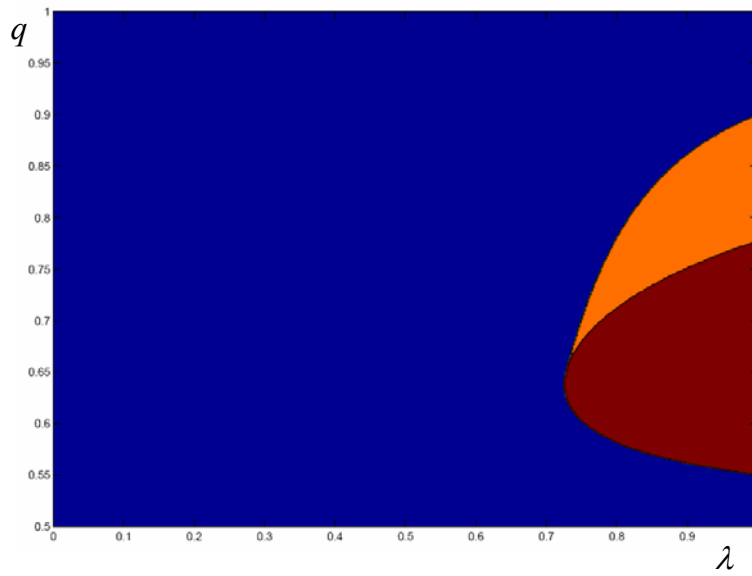
- Flannery, M. J. (1994): “Debt Maturity and the Deadweight Cost of Leverage: Optimally Financing Banking Firms,” *American Economic Review*, 84, 320-331.
- Hart, O. (2001): “Financial Contracting,” *Journal of Economic Literature*, 39, 1079-1100.
- Hart, O., and J. Moore (1994), “A Theory of Debt Based on the Inalienability of Human Capital,” *Quarterly Journal of Economics*, 109, 841-879.
- Hart, O., and J. Moore (1995), “Debt and Seniority: An Analysis of the Role of Hard Claims in Constraining Management,” *American Economic Review*, 85, 567-585.
- Huang, R., and L. Ratnovski (2008), “The Dark Side of Bank Wholesale Funding,” mimeo.
- Jacklin, C. J., and S. Bhattacharya (1988): “Distinguishing Panics and Informationally-Based Bank Runs: Welfare and Policy Implications,” *Journal of Political Economy*, 96, 568-592.
- Myers, S. C. (1977): “Determinants of Corporate Borrowing,” *Journal of Financial Economics*, 5, 147-175.
- Rajan, R. (1992): “Insiders and Outsiders: The Choice between Informed and Arm’s-length Debt,” *Journal of Finance*, 47, 1367-1400.
- Repullo, R. (2005): “Policies for Banking Crises: A Theoretical Framework,” in P. Honohan and L. Laeven (eds.), *Systemic Financial Crises: Containment and Resolution*, Cambridge: Cambridge University Press, 137-168.
- Tirole, J. (2003): “Inefficient Foreign Borrowing: A Dual- and Common-Agency Perspective,” *American Economic Review*, 93, 1678-1702.



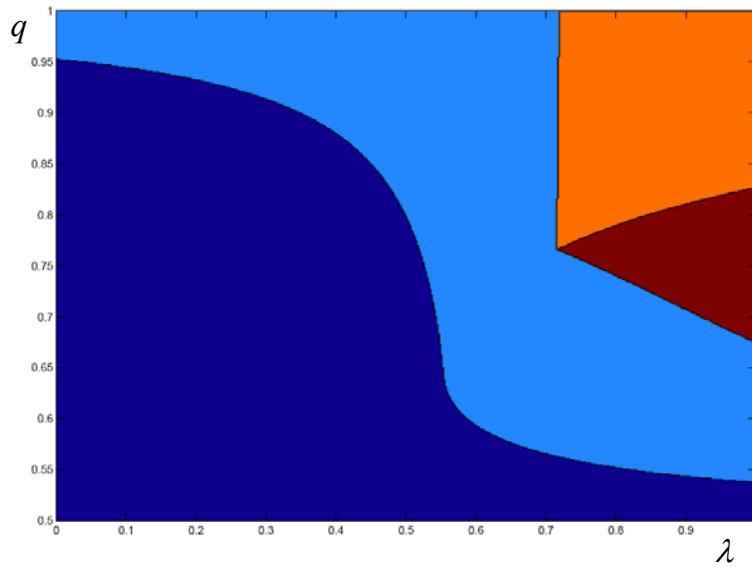
**Figure 1** Characterization of the optimal contract with long-term debt



**Figure 2** Characterization of the optimal contract with risky short-term debt

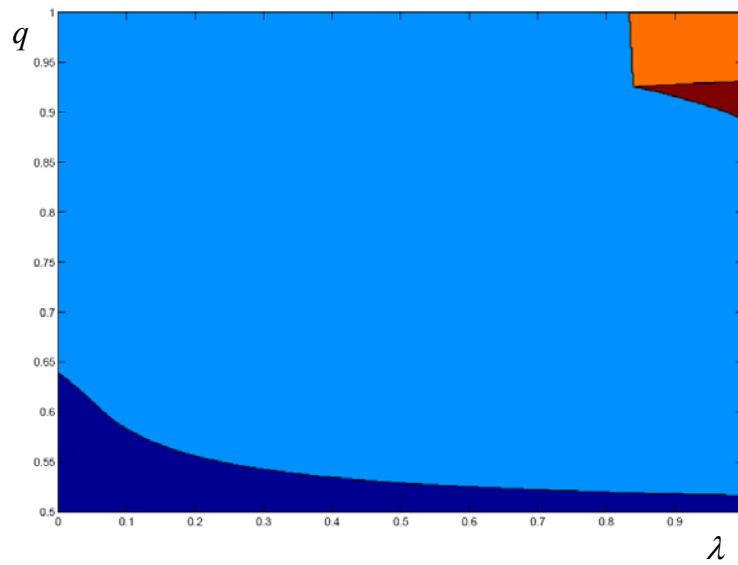


**Figure 3** Combinations of the quality of the lenders' information  $q$  and the recovery rate  $\lambda$  for which ST debt with a zero dividend is optimal (orange region), ST debt with a positive dividend is optimal (red region), and ST debt is not feasible (dark blue region) for a profitability parameter  $a = 1.9$  (for which long-term debt is not feasible).



**Figure 4** Combinations of the quality of the lenders' information  $q$  and the recovery rate  $\lambda$  for which ST debt with a zero dividend dominates LT debt (orange region), ST debt with a positive dividend dominates LT debt (red region), LT debt dominates ST debt (light blue region), and ST debt is not feasible (dark blue region) for a profitability parameter  $a = 2.1$ .





**Figure 5** Combinations of the quality of the lenders' information  $q$  and the recovery rate  $\lambda$  for which ST debt with a zero dividend dominates LT debt (orange region), ST debt with a positive dividend dominates LT debt (red region), LT debt dominates ST debt (light blue region), and ST debt is not feasible (dark blue region) for a profitability parameter  $a = 3.125$ .