



# The dark side of liquidity creation: Leverage and systemic risk



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## ABSTRACT

We consider a model in which the threat of bank liquidations by creditors as well as equity-based compensation incentives both discipline bankers, but with different consequences. Greater use of equity leads to lower ex-ante bank liquidity, whereas greater use of debt leads to a higher probability of inefficient bank liquidation. The bank's privately-optimal capital structure trades off these two costs. With uncertainty about aggregate risk, bank creditors learn from other banks' liquidation decisions. Such inference can lead to contagious liquidations, some of which are inefficient; this is a negative externality that is ignored in privately-optimal bank capital structures. Thus, under plausible conditions, banks choose excessive leverage relative to the socially optimal level, providing a rationale for bank capital regulation. While a blanket regulatory forbearance policy can eliminate contagion, it also eliminates all market discipline. However, a regulator generating its own information about aggregate risk, rather than relying on market signals, can restore efficiency and market discipline by intervening selectively.

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“Any observed statistical regularity will tend to collapse once pressure is placed upon it for control purposes”.

Goodhart (1975)

## 1. Introduction

In ensuring that the risk of the financial system as a whole stays at “prudent” levels, regulators are tasked to meet two forms of regulatory challenges. One is *micro-prudential regulation*, which needs to ensure that risk-taking at the individual bank level is not excessive. The other is *macro-prudential regulation*, which seeks to contain the *systemic risk* that banks may be excessively exposed to collective failure. To date, these two forms of regulation have been typically dealt with in isolation of each other, especially in policy debates. Micro-prudential regulation aims to contain the distorted incentives of banks to make choices that maximize the value of bank shareholders' risk-shifting (or asset-substitution) options, especially in the presence of regulatory put options like deposit insurance.<sup>1</sup> Macro-prudential regulation, on the other hand, focuses

on containing the risk of events like systemic capital and liquidity shortages, manifesting as fire sales and the freezing up of asset markets. Macro-prudential regulation also examines ways in which regulatory interventions like bank bailouts can prevent (or engender) such occurrences and contain (or aggravate) their adverse impact. But since both forms of regulation ultimately seek to enhance financial system stability, a natural question that arises is: what are the micro foundations that possibly link these two forms of regulation? In this paper, we show that not only micro-prudential and macro-prudential regulation affect each other, but that in fact there is a fundamental tension between the two.

Let us explain. Previous papers have noted that uninsured bank debt can increase market discipline and thereby enhance bank loan quality and/or liquidity creation.<sup>2</sup> This notion is also codified in

deposit insurance, a bank has an economic incentive to invest in riskier assets and choose relatively low amounts of capital in its capital structure. This means regulatory monitoring of individual banks is necessary to control excessive risk taking designed to exploit deposit insurance.

<sup>2</sup> Calomiris and Kahn (1991) were the first to formally argue that monitoring by uninsured depositors can result in a bank manager who is making imprudent asset choices being exposed to the threat of a bank run, and that this can induce the manager to shy away from such asset choices. Diamond and Rajan (2001) note that banks invest in assets that are inherently illiquid due to the inability of bank managers to credibly pre-commit to certain actions, and that the threat of a run by uninsured creditors can make these pre-commitments credible, thereby improving liquidity creation by banks. Acharya and Viswanathan (2011) develop this point in

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<sup>1</sup> There is a long history of academic research on micro-prudential regulation. Merton (1977) aptly recognized the isomorphic correspondence between deposit insurance and common stock put options. An important implication was that, given

bank regulation with market discipline being one of the three pillars of Basel II (the other two being regulatory monitoring and capital requirements). This argument about the market discipline of debt is concerned primarily with the attenuation of *bank-specific* risks, and thus it can be viewed as a tool of micro-prudential regulation.

However, high bank leverage has also been held culpable as a contributor to the recent financial crisis. Many have argued that very high financial leverage, especially short-term leverage, induced banks to engage in illiquid and risky lending as well as securities activities that resulted in the widespread failures of these institutions (see e.g., Acharya, Schnabl and Suarez (2013), Adrian and Shin (2010), Goel, et al. (2014), Mian and Sufi (2011), and Shleifer and Vishny (2010)). There appears to be an emerging acceptance of the fact that increases in leverage seem to increase the systemic risk, or the *collective* fragility, of financial institutions. Financial crises are typically associated with a few highly-levered banks, initially suffering portfolio shocks that engender capital or liquidity shortages for those banks, with the malaise quickly ensnaring other banks as the crisis deepens.

As a result, bank-specific and systemic risks, and in turn, micro-prudential and macro-prudential regulation, become difficult to separate. In particular, there emerges a somewhat schizophrenic view of the role of leverage. On the one hand, higher leverage may mean better asset-choices by bank managers and more liquidity when banks are viewed individually. On the other hand, higher leverage also means that the system is more fragile. Faced with circumstances of possible systemic failure, regulatory interventions can play a role in the reduction of *ex-post* fragility. However, it is also precisely in these circumstances that the disciplining effect of the bank's capital structure on *ex-ante* asset choices is compromised and the lines between micro-prudential and macro-prudential regulation begin to become blurred.

The underlying linkage between leverage, *ex-ante* liquidity creation, and *ex-post* systemic risk raise some fundamental questions that we address in this paper.

First, what is the role of bank leverage *vis a vis* equity capital in affecting the bank's *ex-ante* liquidity and portfolio risk? Second, how does maximizing *individual* bank liquidity (a micro-prudential regulation concern) affect *systemic risk* (a macro-prudential regulation concern)? Third, is there a rationale for regulatory intervention, and if yes, under what circumstances? Fourth, how does the regulator affect bank leverage, and what are the implications of this for micro-prudential regulation? That is, when does the regulator interfere with the market discipline role of leverage and what are its (unintended) consequences?

To address these questions, we develop a model of an uninsured bank whose manager has asset-choice flexibility. The bank is *a priori* illiquid because the manager cannot credibly pre-commit to the right asset choices given his personal preference for a private-benefit project. The bank's *ex-ante* liquidity is measured by the financing it can raise by issuing claims against its terminal cash flows. This financing can be any mix of debt and equity. We permit *both* debt and equity to discipline the bank manager to create *ex-ante* liquidity, but this discipline is different depending upon whether it is imposed by debt or equity. Debt disciplines the bank manager by the credible threat that there will be liquidation in some interim states, conditional on interim cash-flow realizations. Equity disciplines the bank manager by providing compensation-based incentives to the manager to select the efficient project. However, since the incentives provided by equity involve payments from *ex-post* cash flows and the managerial dis-

count rate exceeds that of the firm, equity financing reduces the *ex-ante* liquidity of the bank relative to debt financing which can impose discipline without managerial cash payments. Offsetting this *ex-ante* advantage of bank leverage is that it leads to liquidation of the bank in some states, and this liquidation can be *ex-post* inefficient. The bank's privately optimal capital structure is determined by the tradeoff between the *ex-ante* efficiency of leverage relative to equity in the provision of incentives to bankers and the expected *ex-post* cost of inefficient liquidations induced by leverage.

Bank asset portfolios are then allowed to suffer systematic shocks to value that are observed by some of each bank's creditors but not commonly observed by creditors across banks. This means that the (interim) liquidation decision made by the creditors of a bank can be due to either bank-specific information or information about the systematic shock. Since not all creditors of a bank receive information about the systematic shock, but they can observe the liquidation decisions of other creditors, they learn from each other's decisions and update their beliefs about the systematic shock.<sup>3</sup> Their learning is noisy, however, because of the commingling of information about idiosyncratic and systematic risks in any bank's observed liquidation. This can give rise to contagion effects as those creditors of a bank that possess *no* adverse idiosyncratic or systematic risk information about the bank, may choose nonetheless to liquidate their bank at the interim date based solely on observing the liquidations of *other* banks.

We assume that deadweight costs of individual failures are lower than those from joint failures – such as those observed when the whole system or a large portion of it collapses – due to limited re-intermediation of bank activities and failure of payments and settlement systems in such cases. Contagion can then lead to *ex-post* inefficient liquidations in some instances because the creditors of a bank may liquidate their bank based on the mistaken inference that the observed liquidations of other banks are due to a common asset-value shock even when they are due to bank-specific shocks.<sup>4</sup> Thus, one dark side of leverage-based liquidity creation is the attendant systemic risk arising from inefficient contagious liquidations, and the higher the leverage of banks, the greater the systemic risk.

We solve for the bank's privately-optimal capital structure in the presence of the systematic asset-value shock, and the regulator's optimal level of leverage, assuming that the regulator's objective is to maximize the value of the entire banking industry.<sup>5</sup> A divergence between the regulatory and private optima arises because, in choosing its own capital structure, an individual bank internalizes neither the valuable information about the systematic shock conveyed to other banks by its own leverage and creditor-led liquidation (a positive externality) nor the higher likelihood that its liquidation may trigger the inefficient liquidation of another bank (a negative externality). We establish conditions under which the privately-optimal bank leverage will be too high relative to the reg-

<sup>3</sup> For instance, sale and repurchase agreements (repos) are rolled over each morning for dealer banks by financiers such as money market funds. Though a money market fund rolling over a mortgage-backed securities (MBS) repo may not have precise information about the overall quality revision in the housing market for today, they may see (or hear through the grapevine about) other money market funds having not rolled over their repos for some dealer, say Bear Stearns or Lehman Brothers, and, in turn, consider this information while rolling over repos for other dealers.

<sup>4</sup> Note that with the systematic asset-value shock, liquidations are *not* always *ex-post* inefficient since they are sometimes in response to creditors observing a negative shock to asset value of a bank that falls below liquidation value due to the shock, and this negative shock contains relevant information for the asset values of other banks too.

<sup>5</sup> In our model, this objective is equivalent to maximizing the banking industry's aggregate liquidity.

a model where financial intermediaries can switch to riskier assets after borrowing, and short-term debt with strong control rights ensures *ex-ante* liquidity by containing this agency problem.

ulatory optimum.<sup>6</sup> We argue that in order to cope with this, the regulator, may wish to impose ex-ante (countercyclical) capital requirements on banks that are binding during high-asset-valuation periods.

Faced with the prospect of contagion arising from a bank's liquidation, the government regulator can step in with a liquidity infusion that effectively bails out the bank, prevents liquidations, and forestalls a contagion in the form of a system-wide liquidation of banks. We consider the unintended consequences of such intervention under two information regimes.

First, we assume that the regulator can observe neither the idiosyncratic interim financial condition of the bank nor the systematic asset-value-impairment shock, and adopts an unconditional bailout policy. We show in this case that the presence of the regulator can destroy all ex-ante market discipline of debt, as creditors, who anticipate ex-post bailouts, and have no incentives to engage in privately-costly monitoring. This means that there is no asset-value information generated by creditor liquidations, and the absence of the threat of creditor liquidations reduces (debt) market discipline on banks, making micro-prudential regulation more challenging. Somewhat paradoxically, capital structures of banks become irrelevant, as both bank debt and equity need to rely on compensation incentives for the manager. Consequently, the sole reliance on compensation incentives causes the ex-ante liquidity of banks to decline relative to that available in the absence of the regulator, as the pursuit of systemic safety through unconditional bailouts (a macro-prudential regulation goal) compromises the micro-prudential regulation goal of better discipline at the individual bank level.

In one sense, our analysis highlights [Goodhart's \(1975\)](#) Law in that the market discipline of debt collapses once regulators rely upon the manifestation of this discipline in the form of bank liquidations to undertake regulatory interventions. This would – at least to some extent – not be the case if regulatory interventions were based on regulatory intelligence about bank solvency over and above market signals, rather than just based on market signals (such as creditor-led liquidations). This suggests that the regulator may be more effective if accompanied by information generation by central banks or bank regulators that is independent of the information generated by bank creditors.<sup>7</sup> Our analysis can also be viewed as an illustration of the [Lucas Critique \(1976\)](#) in that the macro-prudential effects of the regulator cannot be predicted without accounting for how individual institutions and investors will change their behavior (monitoring by creditors and recapitalization by bank owners, in our model) in response to the change in policy resulting from the introduction of the regulator.

We then examine a second information regime in which the regulator continues to be unable to observe any bank's interim (idiosyncratic) financial condition (which its creditors can observe), but can observe whether the systematic asset-value impairment shock has occurred. In this case, a *selective* intervention policy, wherein the regulator bails out banks *only* if asset values are systematically impaired, eliminates liquidation contagion, but tolerates liquidations triggered by idiosyncratic, bank-specific information possessed by creditors. This serves the twin goals of preserving market discipline and avoiding liquidation contagion, and hence stems from two aspects of our model: first, that joint failures are more socially costly than individual bank failures, and second, that bank creditors provide valuable discipline on bank own-

ers. The policy is consistent with one of [Bagehot's \(1873\)](#) principles for a lender of last resort that should, according to [Bagehot \(1873\)](#), intervene to prevent failures when they threaten the payment system, but allow individual banks to fail when the payment system is not threatened.

Finally, we show each of these regulatory closure or bailout policies affects the design of ex-ante capital requirement. Since the unconditional policy of bailing out all banks that could fail makes leverage have no economic function other than to induce bailouts, the optimal capital requirement in this case is that banks be funded entirely with equity. This is, however, costly in terms of ex-ante bank liquidity. At the other extreme, the policy of no bailouts in any state of the world leads to failure externalities not being internalized by banks so that there is a room for limiting bank leverage through an interior capital requirement in this case. In between these two cases lies the more efficient conditional bailout policy in which the regulator uses its own information to selectively bail out banks when there is a common asset impairment shock. In this case, banks are bailed out only selectively so that social costs of bank failures are limited, and in turn, the capital requirement can allow greater bank leverage (and greater ex-ante bank liquidity) compared to the case of no bailouts. Our analysis makes it clear that the design of ex-ante capital requirements is intimately tied to the regulatory choice of bailout policy. In particular, if the bailout policy can be based on information about systemic risk that is generated by the regulator on top of the information generated by bank debt (through the threat of runs), then the bailout policy can be partly macro-prudential in nature. This is advantageous as this frees up the capital requirements from being excessively conservative and hence bank liquidity is not inefficiently compromised.

While we refer to the “regulator” throughout as a government or quasi-government agency that has the full faith and backing of the government when it comes to committing resources to bail out banks, we could also think of the regulator here as a lender of last resort (LOLR), if we take a broader view of the LOLR than as just a collateralized lender. See [Calomiris et al. \(2016\)](#) for such a view from a historical perspective. The idea is that if the banking system suffers a large enough shock, collateralized lending by the LOLR may not be sufficient to deal with the shock, so bailouts may become a necessary part of the LOLR's policy toolkit.

The rest of the paper is organized as follows. [Section 2](#) provides a brief summary of related literature. [Section 3](#) develops the model. [Section 4](#) contains the analysis of the basic model and shows how leverage helps create both liquidity and systemic risk. [Section 5](#) examines the role of the regulator in controlling or aggravating systemic risk with its choice of ex-ante capital requirements and ex-post bailout policy. [Section 6](#) concludes. All proofs are in [Appendix A](#).

## 2. Related literature

Our paper is related to many strands of the literature. On the topic of micro-prudential regulation of banks, the role of leverage in imposing market discipline on banks has been recognized in numerous papers, as mentioned earlier. See, for example, [Calomiris and Kahn \(1991\)](#), [Dewatripont and Tirole \(1994\)](#),<sup>8</sup> [Diamond and Rajan \(2001\)](#), and [Acharya and Viswanathan \(2011\)](#). Like these papers, we also show how uninsured bank leverage can play a disciplining role. However, in contrast to these papers, we also allow

<sup>6</sup> We also discuss later the conditions under which the bank's privately-optimal leverage is too low compared to the regulatory optimum, although that case is not the focus of our analysis.

<sup>7</sup> An important exception is if the regulators require bank creditors to be segregated by priority and rely on information signals generated by non-contagious or run-prone liabilities of banks, as analyzed by [Hart and Zingales \(2009\)](#).

<sup>8</sup> [Dewatripont and Tirole \(1994\)](#) also discuss how shareholders can affect managerial incentives in banks. Issues of managerial incentives in banks do not arise in the original theories of why banks exist (e.g. [Ramakrishnan and Thakor \(1984\)](#)) because the bank is essentially a cooperative jointly owned by the employees who can monitor each other.

bank equity to discipline the manager, albeit through a different channel, namely incentive compensation that is costly for shareholders to provide as managerial discount rates are greater than those of shareholders. This allows us to examine the tradeoff between disciplining the bank through leverage and disciplining it through equity. Another key difference is that the key force that makes bank leverage socially costly in our model is an *information externality*.

In this respect, the manner in which equity discipline works in our model is different from the way it works in various other papers where high equity capital either induces strong monitoring incentives (e.g., Mehran and Thakor (2011)) or deters asset-substitution moral hazard (see, for example, Bhattacharya et al. (1998) for a review of this literature). Acharya, Mehran and Thakor (2016) have recently pointed out that this role of equity in deterring asset-substitution incentives also produces a tension between having leverage and equity in a bank.

There are also various papers on systemic risk in banking that are related to our work. One strand of research focuses on the effects of risk-sharing on systemic risk. Winton (1997) illustrated the point that “pooling (diversification) elevates *joint* failure risk”.<sup>9</sup> Wagner (2010) shows that while diversification reduces the risk of an individual bank, it increases systemic risk.

Another strand of literature focuses on contagion that arises for reasons other than the kind of information spillover that we examine in this paper.<sup>10</sup> For instance, contagion can also arise due to interconnectedness rather than systematic risk exposures. Caballero and Simsek (2013), for instance, argue that increased complexity due to greater interconnectedness among individual banks and ambiguity aversion to such complexity can generate endogenous risk and crises. Allen et al. (2012) analyze how asset commonality interacts with debt maturity, so that it is short-term debt per se that leads to contagion across banks.<sup>11</sup> Further, there may be a fire-sales related externality as liquidating banks’ creditors seek out scarce liquidity from depositors, raising funding costs for other banks, as in the general equilibrium effect of bank liquidations in Diamond and Rajan (2005). Thakor (2015) develops a model in which the combination of the “availability heuristic” and a long sequence of good outcomes causes all agents to become excessively sanguine about risk taking, leading to episodes of (correlated) high risk taking by banks, whereas Thakor (2016) focuses on how the assessment of risk by financial institutions and its pricing by investors changes with the business cycle, thereby inducing correlations across banks in asset choices at different points in the business cycle. The information contagion we examine is complementary to these channels, but distinct in three respects. First, our model also permits beneficial information contagion. Second, the independently-made endogenous capital structure choices of banks act as a crucial amplification mechanism for contagion. And third,

a given bank’s leverage has a negative information externality for other banks in the sense that it elevates their liquidation probabilities *holding fixed* their leverage levels.

Yet another strand of related research has highlighted that the presence of the LOLR can make more likely the very state of systemic risk (correlated capital and liquidity shortages) that the LOLR is trying to avoid *ex post* (see Acharya and Yorulmazer (2007), Acharya (2009), Acharya, Mehran and Thakor (2016), Buser et al. (1981), Kane (2010), and Farhi and Tirole (2012)). In contrast to these papers, our key point, however, is that the safety nets designed to address leverage-induced systemic risk can destroy the efficiency-based economic rationale, namely market discipline through creditor interventions, for banks to have leverage in the first place. Diamond and Rajan (2012) also highlight that *ex-post* forbearance reduces *ex-ante* liquidity creation by banks by eliminating the threat of runs, and recommend that the central bank adopt a policy that raises interest rates in good times to counter the effect of forbearance. What our analysis contributes additionally on this issue are two important observations. First, the elimination of systemic crises through *ex-post* bailouts necessarily means eliminating the communication of information about asset-value impairment *across* banks, a potentially valuable market mechanism for information aggregation. Second, this undesirable aspect of regulatory intervention is encountered only when the intervention decision is based solely on *market* signals, such as observed bank liquidations. We show that if the regulator generates its *own* information and intervenes *selectively* based on that information, it is possible to eliminate contagion without destroying market discipline.

### 3. The model

This section develops the basic model and the contracting opportunities. Consider an economy in which all agents are risk-neutral and the riskless rate is zero. There are three dates  $t=0, 1, 2$ . There are banks run by managers that choose loan portfolios (or investments) at  $t=0$  that generate payoffs at  $t=1$  and  $t=2$ . There are two types of loans (or projects), both of which require liquidity (investment)  $I$  at  $t=0$ . If this liquidity need is met at  $t=0$ , then the loan generates a random cash flow  $x$  at  $t=1$ , with density function  $g(x)$  and cumulative distribution  $G(x)$ . The support of  $g$  is  $[0, x_{\max}]$ . Each bank is initially owned by shareholders who have no liquidity of their own, so they seek to sell debt and equity claims against the bank in a competitive capital market as to maximize the total value of the bank and hence the revenue raised. Out of this revenue, the manager’s initial wage is paid and the chosen loan portfolio (“loan” henceforth) is financed. The rest is consumed by the initial owners.

#### 3.1. Types of loans

The two types of mutually-exclusive loans available to the bank are the “good” loan and the “private-benefit” loan.<sup>12</sup> The good loan produces a cash flow at  $t=2$  of  $Hx$  with probability  $q \in (0, 1)$ , and zero with probability  $1 - q$ . The private-benefit loan produces a cash flow at  $t=2$  of  $Hx$  with probability  $p \in (0, q)$ , and zero with probability  $1 - p$  at  $t=2$ . Both loans have the same density function of the date-1 cash flow,  $x$ , accruing to the bank. The bank’s manager gets a private benefit of  $B$  per unit of  $x$ , i.e., a total benefit of  $Bx$  at  $t=2$ . We assume that the private-benefit loan is socially inefficient relative to the good loan:

$$qH > [pH + B]. \quad (1)$$

<sup>9</sup> Brunnermeier and Sannikov (2016) develop a model in which banks diversify the idiosyncratic risks of households (with resulting correlations in their equity) and their capacity to act as “diversifiers” depends on their capital.

<sup>10</sup> We note that while information externality from bank runs has been extensively modeled in the literature, see, e.g. Chari and Jagannathan (1988), and recently Acharya and Yorulmazer (2008), in our model information spillover can also be efficient as (some) relevant asset value shocks relevant for a bank’s solvency assessment are obtained only through creditor of other banks (when they “run”).

<sup>11</sup> Moreover, financial innovation incentives can also generate systemic risk as in Thakor (2012). In that model, some institutions take the lead in coming up with innovative products because these generate higher expected rents than “standard” products. The reason is that there may be disagreement about whether the innovation will succeed, and this deters competition. But there is a positive probability of many follower institutions imitating the innovation leader, and when this happens, a systemic risk is generated due to the likelihood that the creditors of these institutions may disagree at a future date that the innovation is good and therefore cut off funding. Huang and Ratnovski (2011) also observe that the possibility of funding being cut off is an aspect of wholesale funding.

<sup>12</sup> The model could also potentially be written in terms of a risk-shifting or asset-substitution moral hazard, instead of a private benefit project, as in Acharya and Viswanathan (2011) or Acharya, Mehran and Thakor (2016).

Moreover, the good loan is socially efficient:

$$qHE(x) > I, \quad (2)$$

where  $E(x)$  is the expected value of  $x$ . The good loan and the private-benefit loan are mutually exclusive. Moreover, the bank manager makes an initial loan choice at  $t = 0$  but can costlessly switch projects at  $t = 1$ .

We assume that all cash flows are pledgeable but we will show that they will not always be pledged in their entirety in equilibrium due to the provision of incentives to bankers. The bank can raise the required initial liquidity via debt or equity whose features we describe next. The debt is uninsured. Moreover, the incumbent bank manager possesses unique human capital to manage either of the two loans. Transferring the management of the loan to another manager substantially reduces loan value.

### 3.2. Debt and equity contracts and assets portfolio liquidity

If the bank raises debt financing at  $t = 0$ , it is assumed that the debt contract contains a covenant whose violation at  $t = 1$  permits the creditors to take control and demand full repayment at  $t = 1$ . Asking for full repayment could result in the bank being liquidated at  $t = 1$  if its interim cash flow is insufficient to make the repayment. Such “accelerated repayment” clauses are standard in debt contracts. If the bank is not liquidated at  $t = 1$ , then it will continue until  $t = 2$ . Another way to think about this is to view the debt contract as short-term, i.e., having a one-period maturity, so that the creditors decide at  $t = 1$  whether to renew funding for an additional period after the debt matures or simply collect whatever the bank can repay at  $t = 1$  and deny renewal of funding.

The face value of debt (promised repayment to creditors) is  $F$ . The date-1 cash flow is pledged to the creditors up to this face value of  $F$ , so the remaining repayment to them at date 2 (in case the bank is not liquidated at date 1) is  $\max(F - x, 0)$ . It is assumed that the liquidation value of the bank at  $t = 1$  is dependent on the realized date-1 cash flow  $x$ . This liquidation value is  $Lx$ . We assume that

$$qH > L > pH + B. \quad (3)$$

That is, liquidation is better than the private-benefit loan under the manager, but worse than the good loan. One way to interpret the liquidation value is to view it as the value of the loan if its management is transferred to another manager.

If equity is used instead of debt, it is assumed that shareholders have no control rights at  $t = 1$  other than over the cash flow  $x$ . That is, shareholders cannot “withdraw” their equity investment in the firm at  $t = 1$  by liquidating the bank. We just take this feature of the equity contract relative to debt as a given. That is, our purpose is not to endogenously derive debt and equity as (constrained) efficient contracts in a security-design setting. However, if the shareholders wish, they can provide incentives for the manager to choose the value-maximizing loan by giving him a suitably chosen share  $\theta \in (0, 1)$  of the shareholders’ payoffs (that is, residual payoffs at date-1 and date-2 after payments to creditors). It is assumed that the manager values this ownership, which represents a claim on future cash flows, at a discount factor  $\rho \in (0, 1)$  of the value assigned by the shareholders. The valuation divergence between the shareholders and the manager could arise from fundamental disagreement (e.g., Boot and Thakor (2011), Boot et al. (2006, 2008), and Van den Steen (2010)) or simply risk-aversion or managerial myopia. It reflects the fact that the manager values his future equity-based compensation less than his up-front fixed wage.<sup>13</sup>

<sup>13</sup> It might well be the case that managers also discount more than shareholders the states in which the firm is liquidated, so that debt-based incentive provision

We assume that a monitoring technology is available to creditors that would enable them to discover the bank’s loan choice at a cost  $\kappa > 0$ . If they dislike this loan choice, they can ask the bank’s manager to change it. If the manager refuses, and financiers are creditors, they can deny renewal of funding at  $t = 1$  for the second period. This lack of funding renewal may force the bank to liquidate in order to meet its repayment obligation. Faced with this prospect, the bank manager may agree to switch loan choice. It follows immediately that the bank’s creditors will refuse to renew funding at  $t = 1$  if they discover the manager has not chosen the loan they desire. If the bank can fully pay off creditors from its cash flow at  $t = 1$  and still continue, it will choose to do so. But if this cash flow is insufficient, then the creditors’ threat of liquidation will have bite and a loan change will occur.<sup>14</sup>

In contrast, if shareholders were to expend  $\kappa$  in monitoring effort and discover a loan choice they did not like, they have no credible threat that they can make to force a change. This is because equity has no finite maturity and shareholders cannot ask for their investment to be returned at  $t = 1$ .<sup>15</sup>

This disciplining role of debt (but not equity) via a withdrawal threat is familiar from the previous work of Calomiris and Kahn (1991), and Diamond and Rajan (2001). The very nature of the debt contract facilitates monitoring-based market discipline that is not possible with equity (see also Hart and Moore (1995)). The fact that creditors can deny renewal of funding at  $t = 1$ —through either a covenant trigger that leads to a demand for accelerated repayment on two-period debt or a denial of renewal of one-period debt—is also similar to repo market funding drying up for financial institutions during the recent crises.<sup>16</sup> While the role of the bank’s creditors as monitors is sometimes questioned on the grounds that these creditors are “outsiders” and therefore should have access to less information than say bank regulators, it should be remembered that these are uninsured bondholders. Thus, they are more like the subordinated debtholders in banks than (insured) depositors. The market discipline potential of subordinated debt has been recognized even in prudential bank regulation, e.g., it is one of the pillars of Basel II.

### 3.3. Lack of pre-commitment

The first-best is achieved if the manager could make a pre-commitment at  $t = 0$  that he will invest in the good loan and not switch at  $t = 1$  to the private-benefit loan. However, we assume that such commitment is not credible other than through incentives provided by debt and equity.

also entails costs to the bank. For simplicity, we do not model these costs. We are implicitly assuming that even when assets are liquidated by creditors, managerial landing is not as hard as that for shareholders as managers may have alternative labor-market options and/or a role to play in the bank’s workout possibly due to asset-specific knowledge not available to creditors, workout specialists or regulators. The primary purpose of  $\rho$ , the divergence between managerial and firm’s discount rates on future cash flows, is to introduce a cost for equity-based governance (in the form of incentive compensation) relative to debt-based governance (in the form of monitoring and contingent liquidations).

<sup>14</sup> Whenever creditors liquidate a bank, it is in their collective best interest to do so. In that sense, a “run” on the bank here is different from a run caused by a coordination failure among depositors as in the usual bank runs story.

<sup>15</sup> Moreover, because of the nature of the equity contract, shareholders have inherently weaker incentives than creditors to liquidate the bank. Continuing (rather than liquidating) is always more attractive for equity than for debt.

<sup>16</sup> When short-term financiers in the repo market became aware of adverse information about financial institutions, the short-term funding they had provided dried up. This aspect of wholesale funding of banks has also recently been examined by Huang and Ratnovski (2011), though they focus only on its negative side-effects.

### 3.4. Managerial compensation

The manager's reservation wage is  $\bar{W} > 0$ . This can be paid with any combination of a fixed wage and incentive compensation. The fixed wage is  $W_f$  and the equity-based compensation is  $W_e$ . The fixed wage is paid up-front at  $t = 0$  and  $W_e$  is paid at  $t = 2$ .

### 3.5. Interim looting by shareholders

If shareholders are permitted to pay themselves a dividend at  $t = 1$ , they can essentially “take their money and run” by paying themselves something analogous to a liquidating dividend. This payment leaves the bank with no cash flow at  $t = 2$ , but the cash flow it generates at  $t = 1$  is lower by an amount  $\ell > 0$  than the expected cash flow of the bank at  $t = 2$  had this “looting” not occurred at  $t = 1$ , i.e., the looting is socially inefficient. This dividend extraction can occur at  $t = 1$  after the bank's creditors have enforced the choice of the preferred loan portfolio and decided to let the bank continue, and it is possible only if a dividend payment is permitted at  $t = 1$ .

There is also a free-cash-flow problem (see Jensen (1986)) such that any cash  $x$  generated at  $t = 1$  that is left in the bank until  $t = 2$  is worth only  $mx$ , with  $m \in (0, 1)$ .

Given these assumptions, it is clear that it is efficient for the bank to pledge its entire interim cash flow  $x$  to creditors. Since paying it out to the shareholders requires permitting a dividend at  $t = 1$  and this can enable the shareholders to inefficiently loot the bank at  $t = 1$  by paying themselves a liquidating dividend (in which the manager will participate due to the equity ownership in his compensation), it will be efficient for the bank to pay it out to the bank's creditors at  $t = 1$  and impose a ban on any dividend payments by the bank at  $t = 1$ .<sup>17</sup>

### 3.6. Systematic shock to asset values

We assume that asset values are subject to a systematic shock, represented by the realized value of an underlying state variable,  $\xi$ , that is experienced at  $t = 1$ . With probability  $\beta \in (0, 1)$ , a systematic asset-value impairment shock is realized as  $\xi = \xi_l$ . This shock lowers the value of  $H$  (for both types of loans) to  $H^- < H$ , with  $qH^- < L$ . With probability  $1 - \beta$ , the state variable is  $\xi = \xi_h$ , and asset value is now higher at  $H^+ > H$ , with  $\beta H^- + [1 - \beta]H^+ = H$ .

### 3.7. The social cost of bank failures

We assume that the failure of a bank creates a social cost that is not directly reflected in the payoffs of the bank's shareholders, creditors or borrowers. There are many ways to interpret these costs. Perhaps the most direct is that bank lending generates positive externalities for the economy by elevating investments by small and medium-sized businesses—the credit supply effect—which then boosts employment, tax revenues and so on, with attendant social benefits. Bank failure will therefore impose a cost by creating a loss of these benefits. Another relevant cost would be that payments and settlement systems could be crippled due to failures of banks and contagious effects on inter-connected banks.<sup>18</sup> Let  $N_n > 0$  be the social cost of failure associated with the failures of  $n$  banks, with  $\partial N_n / \partial n > 0$ ,  $\partial^2 N_n / \partial n^2 > 0$ . The idea

<sup>17</sup> As we saw driving the financial crisis, when capital conservation is a concern, not restricting/banning dividend payments can induce banks to pay out large dividends to expropriate wealth from the creditors. See Acharya et al. (2013).

<sup>18</sup> A less direct benefit of bank lending may be that the higher employment also leads to less crime. Garmise and Moskowitz (2006) document that a reduction in bank lending in a community leads to an increase in crime. Thus, another cost of bank failure may be higher crime.

is that if one bank fails, some of its services can be provided by the remaining banks, but less and less of this re-intermediation is done as more banks fail, so social costs of bank failures increase at an increasing rate.

### 3.8. Observability

We assume that the interim cash flow  $x$  of each bank is not observable to any party other than the bank's shareholders, creditors and the manager. Moreover, the manager's loan choice is not directly observable to anyone but the manager himself, unless financiers intervene and are able to enforce a different loan choice.

The realized value of the systematic shock to a bank's asset value is not observed with certainty by the bank's creditors. The probability that the bank's creditors will observe the systematic-shock signal  $\xi$  is  $\gamma \in (0, 1)$ . Conditional on a particular  $\xi$ , the random variable  $\gamma$  is independent and identically distributed across banks in the economy. The realization of the systematic shock  $\xi$  affecting a bank and the bank's cash flow  $x$  are privately observed (if at all) only by that bank's manager, creditors and shareholders. However, the liquidation of a bank by its creditors is commonly observed by all agents.

The sequence of events in the model is summarized in Fig. 1.

## 4. Analysis of the model

First, we present an analysis of the model developed in the previous section by considering the relative advantages of debt and equity financing when there is no systematic component to the asset value shock. We begin with an analysis of the events at  $t = 1$ , and then we turn to the events at  $t = 0$ .

### 4.1. Analysis of the model without the systematic asset value shock: managerial incentives and creditors' liquidation decision at $t = 1$

Consider first the case in which the bank finances with all equity at  $t = 0$ . To induce the manager to select the good loan at  $t = 1$ , shareholders must provide the manager with equity that represents a fraction  $\theta \in (0, 1)$  of ownership in the bank. The value of  $\theta$  must satisfy the incentive compatibility (IC) constraint point-wise at  $t = 1$  for every realized  $x$ .<sup>19</sup>

$$\rho\theta qHx \geq \rho\theta pHx + Bx.$$

Since this IC constraint is binding in equilibrium, we can write the optimal value of  $\theta$ , call it  $\theta^*$ , as:

$$\theta^* \equiv [H\rho\Delta]^{-1}, \quad (4)$$

where  $\Delta \equiv [q - p]$ . That is, equity provides incentives to the manager via a payoff-contingent compensation contract. To meet the manager's reservation wage, a fixed wage component may also be necessary. The following result is immediate from our assumptions:

**Lemma 1** (Optimality of up-front fixed wage for managers). *If the manager is given a fixed wage,  $W_f$ , it is optimal for the shareholders to pay the fixed wage up-front at  $t = 0$  rather than at a future date.*

The intuition is straightforward. A dollar of compensation at  $t = 0$  is valued by the manager at a dollar, but a claim on a dollar of future compensation is valued by the manager at  $\rho$ . Thus it is cheaper for the shareholders to pay the manager his fixed wage up-front.

<sup>19</sup> The reason why the IC constraint must hold point-wise for every  $x$  realized at  $t = 1$  is that the manager makes his project choice at  $t = 1$  after observing  $x$ .

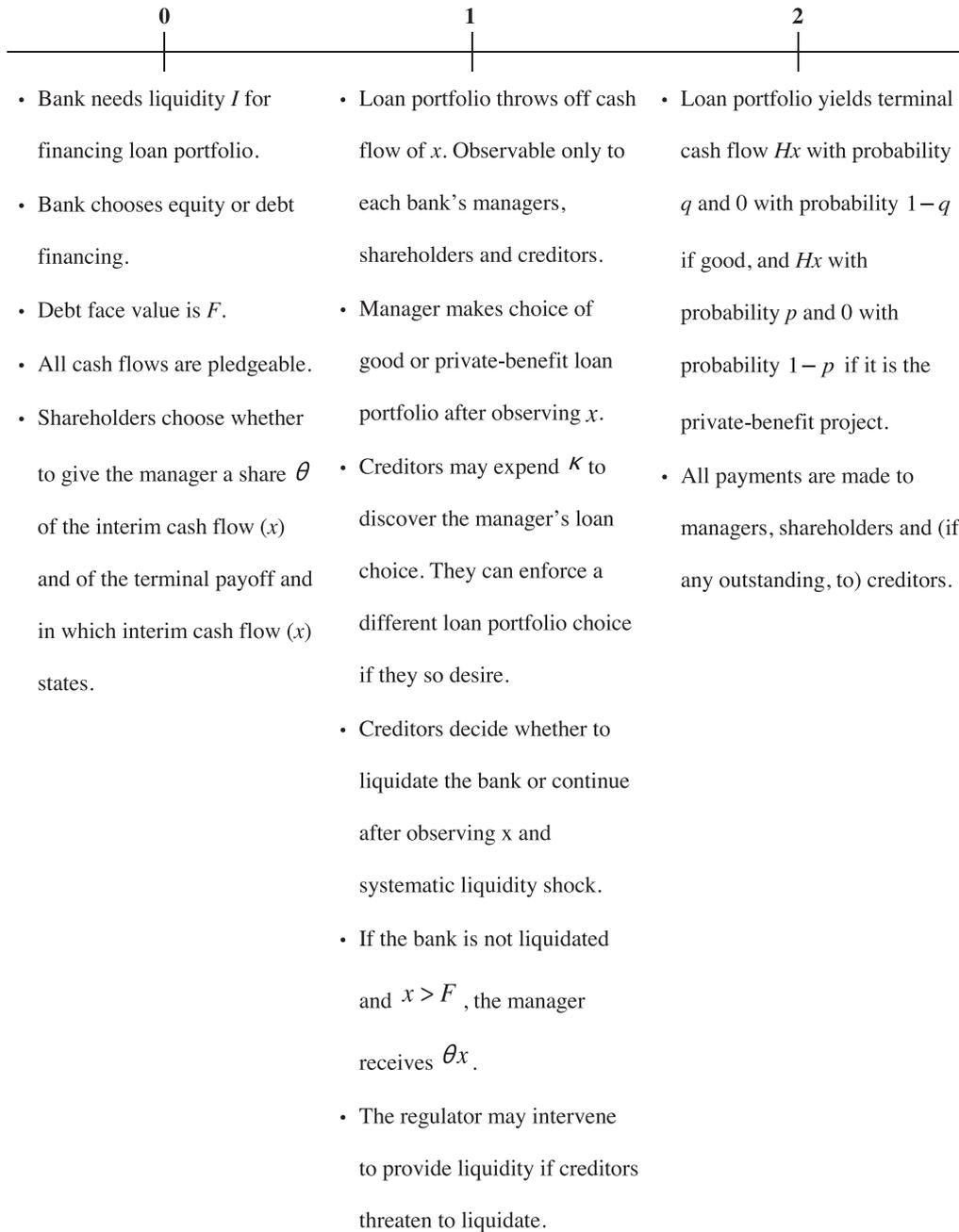


Fig. 1. Sequence of Events.

Next we turn to the case in which the bank has been financed with debt at  $t=0$ . Having collected  $x$  from the date-1 payoff, creditors will assess their payoffs from liquidation and continuation (when they enforce the efficient loan choice) as follows:

$$\text{Liquidate: } \min(Lx, F - x) \quad (5)$$

$$\text{Continue: } q\min(Hx, F - x) \quad (6)$$

We now have the following result:

**Lemma 2** (Creditors' monitoring-contingent liquidation policy without systematic shock). *In absence of the systematic shock  $\xi$ , the bank will adopt a debt contract in which the creditors set the covenant violation trigger at  $F - \kappa[\Delta]^{-1}$ , so that if  $x < F - \kappa[\Delta]^{-1}$  creditors expend  $\kappa$  to discover the manager's loan choice at  $t=1$  and enforce a different loan choice if they so desire. If  $x \geq F - \kappa[\Delta]^{-1}$ ,*

*creditors do not expend  $\kappa$  to investigate, and unconditionally allow the manager to continue with the loan. Conditional on having expended  $\kappa$ , creditors adopt the following liquidation/continuation policy:*

- Continue if  $x \leq \lambda F$ ;
- Liquidate if  $x \in (\lambda F, F - \frac{\kappa}{\Delta})$ ;

*where  $\lambda \equiv q[q + L]^{-1}$ ; All liquidations by creditors are (ex-post) inefficient. When  $x \geq F - \kappa[\Delta]^{-1}$ , shareholders provide incentives to the manager by giving him ownership  $\theta^*$  of the bank's terminal payoff, where  $\theta^*$  is given by (4).*

The different cases are pictorially depicted in Fig. 2. The intuition is that when  $x$  is very high, unconditional continuation is optimal for the creditors at  $t = 1$  because their claim is covered out of just the date-1 cash flow, and it does not matter to them what

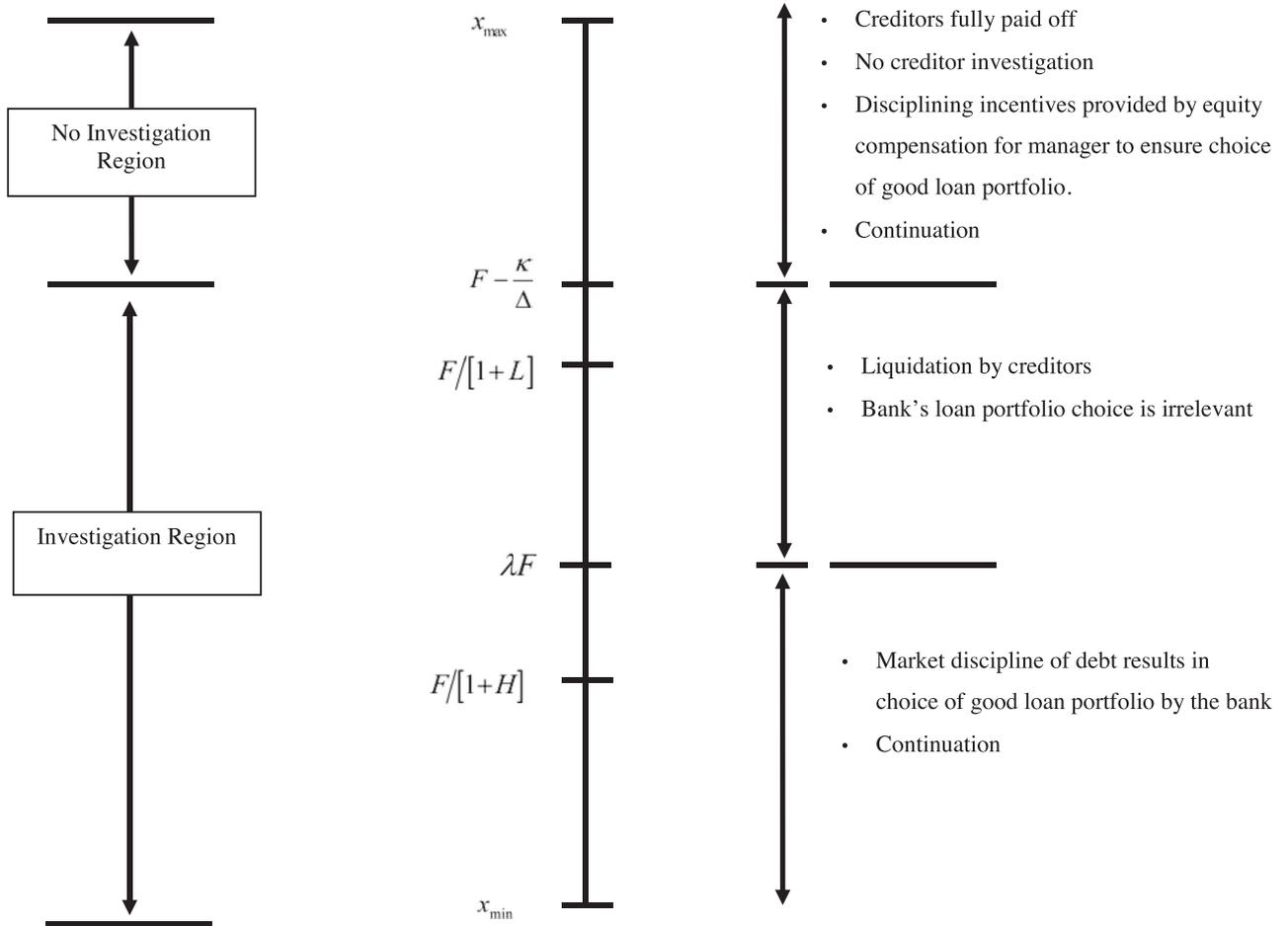


Fig. 2. The Continuation/Liquidation Decision of Creditors.

project the bank invests in. In these states in which creditors are paid off out of the date-1 cash flow, shareholders provide the necessary project-choice incentives for the continuation by awarding the manager an ownership share of the bank. That is, when  $x$  is high, compensation incentives provided by equity replace the monitoring discipline provided by debt. When  $x$  is very low, creditors cannot be paid off fully from the date-1 cash flow, but they prefer to continue rather than liquidate the bank. This is because the liquidation payoff  $Lx$  is so low that it is better for creditors to take a chance on a higher payoff  $qHx$  by continuation. For intermediate values of  $x$ , liquidation is optimal for creditors because they get a sufficiently high certain payoff of  $Lx$  so that given the “risk aversion” induced by concavity of the debt contract, it does not pay for the creditors to gamble on a risky continuation.

This analysis reveals the pros and cons of debt financing. With debt financing, the manager will not have to be provided a compensation incentive over the entire range of  $x$ , as is the case when only equity is used. These incentives need to be provided with debt only when  $x > F - \frac{\kappa}{\Delta}$ . Thus, debt reduces the region over which compensation-based incentives must be provided from  $[0, x_{\max}]$  to  $[F - \frac{\kappa}{\Delta}, x_{\max}]$ . This is the benefit of debt financing.<sup>20</sup> Since performance-based compensation is disliked by the bank manager, it induces a concomitant and compensating upward adjustment in

the manager’s fixed wage, which then reduces the initial maximum liquidity the firm can raise via external financing at  $t=0$ . This *ex-ante* liquidity reduction is reduced with debt financing. The disadvantage of debt financing is that it creates a region  $[\lambda F, F - \frac{\kappa}{\Delta}]$  over which the bank is (*ex-post*) inefficiently liquidated. In what follows, we shall assume that  $\kappa$  is arbitrarily small by letting  $\kappa = 0$  because doing so reduces notation without qualitatively affecting the analysis.

4.2. The bank’s optimal capital structure without the systematic asset value shock

For simplicity, it will be assumed now that  $g(\cdot)$  is uniform on  $[0, x_{\max}]$ . Let  $W_e(F, \theta)$  be the manager’s equity compensation as assessed by the shareholders, and let  $W_f(F, \theta)$  be the fixed wage. Both are functions of the face value of the bank’s debt and the fractional ownership  $\theta^*$  given to the manager. Thus,

$$W_e(F, \theta^*) = \theta^* \int_x^F [(x - F) + qHx]g(x)dx, \tag{7}$$

where  $E(\cdot)$  is the expectation operator and  $\theta^*$  is given in (4). The manager’s valuation of his equity compensation, denoted  $W_m(F, \theta^*)$ , is:

$$W_m(F, \theta^*) = \rho\theta^* \int_x^F [(x - F) + qHx]g(x)dx. \tag{8}$$

Then, assuming a competitive market among banks for hiring managers, it can be shown that the manager’s reservation utility

<sup>20</sup> One implication of this feature of our model is that in banks with (exogenously) greater leverage, managerial compensation is less important for incentive purposes and thus a manager’s compensation package would feature a greater share of fixed or “pay without performance” component.

constraint will be binding in equilibrium, so that the manager's fixed wage is:

$$W_f(F, \theta^*) = \bar{W} - W_m(F, \theta). \quad (9)$$

Given the liquidation and continuation regions identified in Lemma 2, we can write the bank's optimal capital structure as the solution to the following problem of maximizing the total value,  $V(F)$ , of the bank:

$$\begin{aligned} \text{Max}_F V(F) = & E(x) + qH \int_0^{\lambda F} \left( \frac{x}{x_{\max}} \right) dx + \int_{\lambda F}^F \left( \frac{Lx}{x_{\max}} \right) dx \\ & + qH \int_F^{x_{\max}} \left( \frac{x}{x_{\max}} \right) dx - W_e(F, \theta^*) - W_f(F, \theta^*) \end{aligned} \quad (10)$$

It is convenient to define an upper bound on the manager's private benefit as:

$$\bar{B} \equiv \frac{\Delta[1 - \lambda^2][qH - L]}{q[1 - \rho]}. \quad (11)$$

We now obtain the following result.

**Proposition 1** (Bank's optimal capital structure). *Assume  $B < \bar{B}$ . Then the bank's optimal (value-maximizing) capital structure includes an amount of debt financing  $F^* \in (0, x_{\max})$  where:*

$$F^* = \frac{x_{\max}}{\{[1 - \lambda^2][qH - L][\{1 - \rho\}\theta^*]^{-1} - [qH - 1]\}}. \quad (12)$$

The condition that  $B$  not be too large is needed because otherwise the need for debt discipline is so large that the bank goes to a corner optimum of all debt. As long as this is not the case, there is an interior value of leverage,  $F^*$ , that maximizes the value of the bank. This optimal value balances the cost of inefficient liquidation due to leverage against the benefit of leverage in disciplining the manager without the dissipative cost of incentivizing him with equity.

The next result provides comparative statics on  $F^*$ .

**Corollary 1** (Comparative statics on the bank's optimal leverage).  *$F^*$  is increasing in the manager's private benefit,  $B$ , and decreasing in the manager's discount factor for equity valuation,  $\rho$ .*

This result is intuitive. As  $B$  increases, the need for debt discipline grows and leads to higher optimal leverage. As the manager's discount factor,  $\rho$ , increases, using equity compensation to incentivize him becomes less expensive, so optimal leverage declines.

#### 4.3. Analysis of the model with the systematic asset-value shock: the creditors' liquidation decision at $t = 1$

Thus far, we have examined the monitoring and liquidation decisions of creditors and the contracting decision of banks when asset values are not subject to the systematic asset-value shock. We now include this systematic shock, so that one bank's liquidation can convey information about the shock to another bank.

Imagine there are two banks in the economy and conditional on the systematic shock  $\xi$ , each bank is faced with identically and independently distributed (i.i.d.) shocks. In this two-bank economy, we also need to specify how the banks observe each other's liquidation outcomes and how this affects the liquidation decisions of creditors of each bank. We model this as a two-stage game.

First, each bank's creditors announce, simultaneously with the creditors of the other bank, whether they will liquidate the bank based solely on their own information about the bank. In this state, neither bank's creditors have access to the decision of the other bank's creditors.

Second, after having observed each other's first-stage liquidation outcomes, each bank's creditors decide whether they wish to liquidate in the second stage (provided they did not liquidate in

the first stage). In particular, bank  $i$ 's creditors have *no* incentive to decide not to liquidate in stage 2 if they decided to liquidate in stage 1.<sup>21</sup> But, after observing the creditors of the other bank liquidate, they may decide to liquidate in stage 2 even if they announced in stage 1 that they would not liquidate. We assume (and derive a condition below) such that if a bank is liquidated, the inference about  $\xi$  for the creditors of the other bank is sufficiently adverse that they liquidate too.

Note that conditional on the creditors observing  $\xi = \xi_\ell$ , the creditors will liquidate if

$$qH^- < L, \quad (13)$$

which we assumed earlier. To figure out the sufficient condition for our assumption that the creditors of bank  $i$  will liquidate in stage 2 if they observe the creditors of bank  $j$  liquidating, let us calculate the posterior belief of creditors of bank  $i$  (if they observe the creditors of bank  $j$  liquidating) concerning the aggregate shock being adverse. At this stage, we need to introduce some notation that is useful for examining the inference problem from the perspective of bank  $i$ . Define for bank  $j$ :

$$\delta^j \equiv \Pr[x \in (\lambda F_j, F_j)] = \frac{F_j - \lambda F_j}{x_{\max}} = \frac{[1 - \lambda]F_j}{x_{\max}}, \quad (14)$$

$$\delta_1^j \equiv \beta[1 - \gamma]^2[1 - \delta^j], \text{ and} \quad (15)$$

$$\delta_2^j \equiv [1 - \beta][\gamma + [1 - \gamma][1 - \delta^j]]. \quad (16)$$

Note that  $\delta^j$  is simply the probability that bank  $j$ 's  $x \in (\lambda F_j, F_j)$  and hence it is liquidated by its creditors solely due to the realization of its own cash flow.

Next,  $\delta_1^j$  is the joint probability that the adverse asset-value shock was realized (the probability that  $\xi = \xi_\ell$  is  $\beta$ ), neither bank observed the shock (probability  $(1 - \gamma)^2$ ), and bank  $j$  did *not* liquidate due to a cash-flow realization  $x \in (\lambda F_j, F_j)$  (the probability that  $x \notin (\lambda F_j, F_j)$  for bank  $j$  is  $1 - \delta^j$ ).

Similarly,  $\delta_2^j$  is the joint probability that the favorable asset-value shock was realized (probability  $1 - \beta$ ), and either (i) it was observed by the bank  $j$  (probability  $\gamma$ ), or (ii) it was not observed by bank  $j$  (probability  $1 - \gamma$ ) and bank  $j$  did not liquidate due to its own realization of  $x$  being in  $(\lambda F_j, F_j)$  (which has probability  $1 - \delta^j$ ). Thus,  $\delta_1^j + \delta_2^j$  is the probability that bank  $i$  is *not liquidated* when its own  $x \in (0, \lambda F_i)$ , i.e., the probability that it is not liquidated when its own interim loan cash flow is low enough to not warrant liquidation on the basis of that cash flow.

In calculating the posterior belief that the aggregate shock is adverse, what we are assuming is that the bank in question (bank  $i$ ) did not receive the signal about the shock, decided *not* to liquidate in stage 1 but observed the other bank (bank  $j$ ) liquidating in stage 1. Then bank  $i$  forms the following posterior belief about  $\xi$ :

$$\begin{aligned} \Pr(\xi = \xi_\ell | \text{bank } j \text{ announced liquidation in stage 1}) &= \frac{\Pr(\text{bank } j \text{ liquidated in stage 1} | \xi = \xi_\ell) \Pr(\xi = \xi_\ell)}{\Pr(\text{bank } j \text{ liquidated in stage 1})} \\ &= \left( \frac{[\gamma \lambda F_j [x_{\max}]^{-1} + \delta^j] \beta}{\{[\gamma \lambda F_j [x_{\max}]^{-1} + \delta^j] \beta + [1 - \beta][\delta^j]\}} \right) \\ &= \left[ \frac{[F_j - [1 - \gamma]\lambda F_j] \beta}{[\beta \gamma \lambda F_j + F_j [1 - \lambda]]} \right] \\ &= \frac{[1 - \lambda][1 - \gamma] \beta}{\{1 - \lambda[1 - \gamma] - (1 - \lambda)\} \beta + 1 - \lambda} \equiv \hat{\beta}. \end{aligned} \quad (17)$$

<sup>21</sup> There are no strategic manipulation incentives in the model. In particular, there is nothing to be gained for the creditors in one bank from liquidating or not liquidating a bank in order to strategically manipulate the behavior of creditors in another bank.

Note that this probability is positive only if bank  $i$  did not observe  $\xi = \xi_h$  in the first stage. Further  $\hat{\beta} > \beta$ .

To understand the numerator of (17), note that, conditional on  $\xi = \xi_\ell$ , bank  $j$  can be liquidated in one of two cases: (i) if its creditors observe  $\xi$  (which has probability  $\gamma$ ) and bank  $j$ 's cash flow  $x \leq \lambda F_j$  (which has probability  $\lambda F_j [x_{\max}]^{-1}$ ), or (ii) bank  $j$ 's cash flow realization  $x \in (\lambda F_j, F_j)$  (which has probability  $\delta^j$ ). Hence, the probability of being in one of these two states is  $\lambda F [x_{\max}]^{-1} + \delta^j$ . This probability is multiplied with  $\beta$ , the probability that  $\xi = \xi_\ell$ . In the denominator, there is an additional term,  $[1 - \beta]$ , which is the probability that bank  $j$  is liquidated due to its  $x \in (\lambda F_j, F_j)$  even when  $\xi = \xi_h$  (which has probability  $[1 - \beta]$ ).

Now, for bank  $i$ 's creditors to decide to liquidate (only) after having observed bank  $j$ 's creditors liquidations, we need two conditions:

**Condition 1.** Creditors will not unconditionally liquidate before observing  $\xi$  or a liquidation of another bank:

$$q[\beta H^- + [1 - \beta]H^+] > L,$$

which implies

$$qH > L, \quad (18)$$

which we have assumed throughout.

**Condition 2.** It pays for the creditors of bank  $i$  to liquidate if they observe liquidation by the creditors of bank  $j$ :

$$q[\hat{\beta}H^- + [1 - \hat{\beta}]H^+] < L \quad (19)$$

where  $\hat{\beta}$  is defined in (17). Define  $\bar{L}$  as the value of  $L$  at which (19) holds as an equality, so that the inequality in (19) will hold for all  $L > \bar{L}$ .

**Condition 3.** When both banks are liquidated, the liquidations are socially inefficient, although liquidation of only one bank based on observing  $\xi = \xi_\ell$  is efficient.

$$2qH^- + N_2 > 2L \quad (20)$$

$$qH^- + N_1 < L \quad (21)$$

Given conditions under which the creditors of bank  $j$  liquidate if they observe liquidation by the creditors of bank  $i$ , the probability that bank  $j$  will not be liquidated is

$$\delta_0 = [1 - \delta^j]^2 \{ \beta [1 - \gamma]^2 + [1 - \beta] \} \quad (22)$$

since not being liquidated requires that no bank's creditors liquidate, due to adverse cash flow shocks (probability  $[1 - \delta^j]^2$ ) and either that neither bank's creditors observe the adverse systematic shock if it occurs (probability  $\beta [1 - \gamma]^2$ ) or that the adverse systematic shock did not occur (probability  $1 - \beta$ ).

We now have:

**Proposition 2** (Dependence of a bank's liquidation probability on its own leverage and the other bank's leverage). For a given leverage of bank  $j$ ,  $F_j$ , the (unconditional) ex-ante probability of liquidation of bank  $i$  is increasing in bank  $i$ 's leverage,  $F_i$ . Moreover, fixing its own leverage,  $F_i$ , the unconditional probability of liquidation of bank  $i$  is increasing in bank  $j$ 's leverage,  $F_j$ .

The intuition can be seen by observing that higher leverage of bank  $j$  makes it more likely that bank  $j$  will be liquidated. This is because higher leverage of bank  $j$  reduces the probability that bank  $j$ 's interim cash flow,  $x$ , will exceed its leverage  $F_j$ . Wherever bank  $j$  is liquidated, bank  $i$ 's creditors noisily infer that state  $\xi = \xi_\ell$  is likely to have occurred, and liquidate bank  $i$ .

Recall that in the previous analysis that was conducted in the absence of the systematic asset-value shock  $\xi$ , any liquidation by

a bank's creditors was ex-post inefficient (see Lemma 2). That is no longer true, however, when the systematic asset-value shock  $\xi$  is introduced. Now there can be an ex-post efficiency gain from liquidation in the case where the creditors of bank  $i$  do not observe  $\xi$  but liquidate based upon observing the liquidation of bank  $j$  whose creditors observe  $\xi = \xi_\ell$ . Proposition 2 shows that bank  $i$ 's own leverage increases the probability of liquidation of bank  $i$ . Thus, an increase in a bank's leverage contributes to ex-post efficiency in such states. Hence, with the introduction of the systematic asset-value shock, leverage-induced liquidity creation has both a *dark side* (liquidations that are sometimes inefficient) and a *bright side* from an ex-post standpoint.<sup>22</sup> It is the dark side that contributes to a leverage-engendered increase in systemic risk.

Note also that we have assumed that creditors in different banks are distinct. What if say a single creditor could take diversified positions in all banks? On the one hand, this will eliminate inefficient liquidations because there is no contagion to worry about. On the other hand, efficient liquidations will also decline because the probability of receiving information about the systematic shock will be limited to the probability that one bank will receive this signal.

#### 4.4. The value of the levered bank and optimal leverage at $t = 0$

We can now move to  $t=0$  and examine the bank's optimal capital structure decision with the systematic asset-value shock. Now bank  $i$ 's value function can be written as:

$$\begin{aligned} V(F_i) = & E(x) + \int_{\lambda F_i}^{F_i} \left( \frac{Lx}{x_{\max}} \right) dx + qH \int_{F_i}^{x_{\max}} \left( \frac{x}{x_{\max}} \right) dx \\ & + [\delta_1^j H^- + \delta_2^j H^+] q \int_0^{\lambda F_i} \left( \frac{x}{x_{\max}} \right) dx \\ & + [1 - \delta_1^j - \delta_2^j] L \int_0^{\lambda F_i} \left( \frac{x}{x_{\max}} \right) dx \\ & - W_e(F_i, \theta^*) - W_f(F_i, \theta^*). \end{aligned} \quad (23)$$

To understand (23), note that its structure is similar to (10). The first term,  $E(x)$ , is the expected value of the interim cash flow.

The second term is the liquidation by creditors of bank  $i$  that occurs when  $x \in [\lambda F_i, F_i]$ , and the value is  $Lx$ . Note that, given condition 2, bank  $i$  knows that if it liquidates, so will bank  $j$ .

The third term refers to the state  $x \in (F_i, x_{\max}]$ . In this state, there is no liquidation or creditor monitoring of bank  $i$ , so the manager is incentivized by shareholders with an equity compensation contract.

To understand the fourth term, note that  $1 - \delta_1^j - \delta_2^j$  is the probability of liquidation of bank  $i$  that is *not* based on bank  $i$ 's realization of  $x$  when  $x \in [0, \lambda F_i]$ , but based on that of bank  $j$ , and  $\delta_1^j + \delta_2^j$  is the probability of *no liquidation* of bank  $i$ , when  $x \in [0, \lambda F_i]$ . As explained earlier,  $\delta_1^j$  is the joint probability of  $\xi = \xi_\ell$  and no liquidation of bank  $j$ , and  $\delta_2^j$  is the joint probability of  $\xi = \xi_h$  and no liquidation of bank  $j$ . Note also that if  $\xi = \xi_\ell$  is realized, the expected value of date-2 cash flows is  $qH^-$  per unit of  $x$  and if  $\xi = \xi_h$  is realized, this value is  $qH^+$  per unit of  $x$ . This explains the fourth term.

The fifth term refers to the liquidation of bank  $i$  that occurs because creditors observe the liquidation of the *other* bank  $j$ , i.e., this is liquidation that is not based on bank  $i$ 's own  $x$ . This occurs with probability  $1 - \delta_1^j - \delta_2^j$  when for bank  $i$  we have  $x \in [0, \lambda F_i]$ , and the liquidation payoff is  $Lx$ .

<sup>22</sup> We have conducted this analysis for the two-bank case to convey these ideas as transparently as possible. The  $n$ -bank case, with  $n > 2$ , is qualitatively similar, although it permits a weakening of the restrictions on the exogenous parameters that are needed for the dark side of leverage, i.e., the liquidation contagion.

The equity compensation shows up in the sixth term (recall that the seventh term is the fixed compensation).

Now, note that the leverage of the other bank,  $j$ , is contained in the probabilities  $\delta_1^j$  and  $\delta_2^j$ . Formally, let  $V_i(F_i, F_j)$  denote the value of bank  $i$  given the leverage of the two banks  $F_i$  and  $F_j$ . Then the best-response of bank  $i$  in terms of its leverage choice  $F_i^0(F_j^0)$  maximizes  $V_i(F_i, F_j^0)$  for a given leverage of bank  $j$ ,  $F_j^0$ . The Nash equilibrium of private leverage choices  $(\bar{F}_i, \bar{F}_j)$  satisfies the fixed-point property  $\bar{F}_i = F_i^0(\bar{F}_j)$  and  $\bar{F}_j = F_j^0(\bar{F}_i)$ .

Define:

$$\bar{\delta} \equiv \frac{[1 - \lambda]qHx_{\max}}{x_{\max}} = [1 - \lambda]qH \quad (24)$$

and assume that the symmetry condition  $L - H^- = H^+ - L$  holds and that  $\beta \leq 0.5$ . Note that  $\bar{\delta}^j$  takes when the face value of debt is at its maximum possible value,  $qH_{\max}$ , ignoring the managerial wage. Further, define:

$$\hat{B} \equiv \frac{\Delta[qH - L - \lambda^2\{\bar{\delta}_2[H^+ - L] - \bar{\delta}_1[L - H^-]\}]}{[1 - \rho]q} \quad (25)$$

where

$$\bar{\delta}_1 \equiv \beta[1 - \gamma]^2[1 - \bar{\delta}]$$

$$\bar{\delta}_2 \equiv [1 - \beta\{\gamma + [1 - \gamma][1 - \bar{\delta}]\}]$$

$\hat{B}$  is similar to the  $\bar{B}$  defined in (11). The following result is useful.

**Lemma 3.** Define

$$\tilde{B}(F_j) \equiv \frac{\Delta[qH - L - \lambda^2\{\delta_2^j[H^+ - L] - \delta_1^j[L - H^-]\}]}{[1 - \rho]q} \quad (26)$$

Then  $\partial \tilde{B}(F_j) / \partial \delta^j < 0$ .

This means that  $\tilde{B}(F_j)$  is minimized when  $\delta^j$  takes its maximum value, which occurs when  $F_j$  is at its maximum possible value. Thus, where the infimum is over all possible values of  $F_j$ :  $\hat{B} \leq \inf \tilde{B}(F_j)$ . Defining  $\hat{B}$  this way allows us to state the following characterization of the best responses and the symmetric Nash equilibrium, without having  $\hat{B}$  depend on the actual leverage choice of any bank.

**Proposition 3** (Optimal capital structure of each bank in symmetric Nash equilibrium). Assume  $B < \hat{B}$ . Then, in any Nash equilibrium, bank  $i$ 's best response,  $F_i^0(F_j^0)$ , at  $t=0$  to bank  $j$ 's (privately-optimal) leverage,  $F_j^0$ , is:

$$F_i^0(F_j^0) = \frac{[1 - \rho]\theta^*x_{\max}}{\{qH - [1 - \rho]\theta^*[qH - 1] - [L + \lambda^2\{\delta_2^j[H^+ - L] - \delta_1^j[L - H^-]\}]\}}, \quad (27)$$

where  $\delta_2^j$  and  $\delta_1^j$  are functions of  $F_j^0$ . In a symmetric Nash equilibrium, each bank's privately-optimal leverage is:

$$\bar{F}_i = F_i(F_j^0) = F_j^0(F_i^0) = \bar{F}_j = F^0 = \frac{\sqrt{a^2 + 4b} - a}{2b} \quad (28)$$

$$\text{where } a \equiv \frac{[qH - [1 - \rho]\theta^*[qH - 1] - \lambda^2[H - L][1 - 2\beta + 2\beta\gamma - \beta\gamma^2]}{[1 - \rho]\theta^*x_{\max}},$$

$$b \equiv \frac{[\lambda^2[H - L][1 - \gamma][1 - \beta\{2 - \gamma\}][1 - \lambda]]}{[1 - \rho]\theta^*x_{\max}^2}.$$

Moreover,  $F^0 \in (0, x_{\max})$ .

The condition that the manager's private benefit not be too large is required for the same reasons that were discussed earlier.

The proposition characterizes the best response of a bank in terms of its choice of leverage (given the leverage of the other bank) that maximizes the value of the bank and hence its *ex-ante* liquidity. The proposition asserts that  $F^0$  is a unique symmetric Nash equilibrium outcome. Note that each bank's leverage choice has to be examined as part of a Nash equilibrium because each bank's leverage affects the other bank's expected payoff (formally through  $\delta_1^j$  and  $\delta_2^j$ ), and each bank's best response in any equilibrium must satisfy (27). While (27) expresses each bank's leverage as a function of the other bank's leverage, (28) expresses the symmetric Nash equilibrium choice purely as a function of exogenous parameters (recall  $\theta^*$  is expressed purely as a function of exogenous parameters via (4)).

The following corollary establishes comparative statics on  $F^0$ .

**Corollary 2** (Comparative statics on optimal capital structure). The privately optimal leverage  $F^0$  is increasing in the manager's private benefit,  $B$ , and the likelihood,  $\gamma$ , that the systematic state is visible to bank creditors, and decreasing in the probability,  $\beta$ , of the systematic asset-value impairment shock, and the managerial discount factor,  $\rho$ .

The intuition for the impact of  $B$  on  $F^0$  is similar to that in our earlier discussion. As (22) clarifies, an increase in  $B$  increases  $\theta^*$  and the illiquidity arising due to equity-based compensation, and debt becomes more attractive. The intuition for  $\gamma$  is straightforward in that as debt becomes more informed about the nature of the systematic shock, inefficient liquidations by creditors are fewer and the deadweight costs due to debt become lower.

Finally, the intuition for the impact of  $\beta$  is as follows. The main role of leverage is to discipline the manager via the threat of bank liquidation. While bank liquidation by creditors, based on having observed a signal that asset value is impaired, also requires the presence of some leverage, the probability that the creditors of bank  $i$  will observe this signal is unaffected by the leverage of bank  $i$ . When  $\beta$  increases, it becomes more likely, *ceteris paribus*, that the creditors of bank  $i$  will liquidate based on observing a liquidation of bank  $j$ . This contagion effect makes debt less attractive *ex ante*. Finally, as the manager's discount for equity-based compensation decreases (that is, the value the manager assigns to risk-based compensation goes up), the attractiveness of debt declines relative to equity financing.

## 5. The effect of a regulator

We now examine the role of the regulator. We think of the regulator as a government or a central bank that has two policy instruments at its disposal: (i) *ex-ante* capital requirements and (ii) bailing out failed banks *ex post*. We assume that the regulator's *ex-ante* objective is to maximize

$$V_i + V_j - \text{expected social cost of bank failures} - \text{expected costs of regulatory actions} \quad (29)$$

i.e., the sum of the values of the two banks minus the expected social cost of bank failures but also subtracting the cost of any regulatory interventions.

We will examine three cases. The first case is when the regulator pre-commits to not bailing out any failed bank. The next two cases capture less pre-commitment of this sort. The second case is when the regulator adopts an unconditional bailout policy (bail out all failing banks). The final case is that of a conditional bailout policy (bail out banks only in some circumstances as we elaborate below). The bailout policy will affect the private sector's choice of capital structure. In turn, the capital requirement that the regulator designs *ex ante* will take account of, and depend on, the bailout policy in place.

The regulatory costs of bailouts will in general depend on the extent of leverage that is being supported with taxpayer funds in

the bailouts. For tractability, we will assume that this is not the case and instead assume simply that the cost of bailing out one bank is  $C_1$  and the cost of bailout out both banks is  $C_2$ .

We further assume that  $C_1 > N_1$  and  $C_2 < N_2$ . These assumptions imply that from an ex-post standpoint it is never optimal to bail out an individual bank if the social costs associated with bank failure are limited to that one bank only, whereas it is always optimal ex post to bail out both banks if they are both going to fail (either due to adverse shocks for both banks or due to adverse shock to one bank and contagion from that failure to the other bank). This is meant to capture Bagehot's (1873) idea that the LOLR should not bail out (or assist) individual banks that are insolvent, but should intervene when the payment system is threatened due to a meltdown of the whole banking system.<sup>23</sup>

#### Case 1. Regulator never bails out banks

In this case, the regulators seek to set a minimum capital requirement for each bank that maximizes (29) assuming there are no ex-post bailouts.

Next, we examine how the Nash equilibrium of privately-optimal leverage choices compares with the regulatory optimum. The regulator's optimal leverage choice  $(\hat{F}_i, \hat{F}_j)$  takes account of the externalities of bank leverage on other banks and in particular the social cost of joint bank failures. That is, recognizing that if bank  $i$  fails, so will bank  $j$ , the regulatory problem is to maximize  $V_i(F_i, F_j) + V_j(F_i, F_j) - [1 - \delta_0]N_2$ , whose first-order conditions are given by

$$\frac{\partial V_i}{\partial F_i} + \frac{\partial V_j}{\partial F_i} - N_2 \partial[1 - \delta_0] / \partial F_i = 0 \quad (30)$$

$$\frac{\partial V_i}{\partial F_j} + \frac{\partial V_j}{\partial F_j} - N_2 \partial[1 - \delta_0] / \partial F_j = 0 \quad (31)$$

where we recall that  $\delta_0 = [1 - \delta^i][1 - \delta^j]\{\beta[1 - \gamma]^2 + 1 - \beta\}$ . In contrast, the private optimum satisfies  $\frac{\partial V_i}{\partial F_i} = 0$  and  $\frac{\partial V_j}{\partial F_j} = 0$ .

Recall that we are assuming the symmetry condition  $L - H^- = H^+ - L$ .

Then, we obtain the following intuitive result (focusing on the symmetric case as before):

**Proposition 4** (Dark side of liquidity creation: comparison of privately-optimal and socially-optimal capital structures with no regulatory bailouts). *The regulator's problem of finding the regulatory optimum is a convex optimization problem with a unique symmetric global optimum. In the (symmetric) Nash equilibrium involving banks  $i$  and  $j$ , the privately-optimal leverage  $F^0$  exceeds the socially optimal leverage  $\hat{F}$ , regardless of  $N_2$  if  $\beta \leq 0.5$ , and regardless of  $\beta$  if  $N_2$  is sufficiently large.*

This proposition captures the essence of our main point highlighting the systemic risk induced by leverage-based creation of liquidity. As discussed earlier, the main role of leverage is to discipline the manager. However, as bank  $i$ 's privately-optimal leverage increases, its negative impact on the value of bank  $j$ —which derives no benefit from better discipline at bank  $i$ —also increases; recall that this negative impact arises from bank  $j$  being inefficiently liquidated when bank  $i$  is liquidated only because of an adverse idiosyncratic cash flow realization. Moreover, because higher leverage by bank  $i$  results in higher liquidation probabilities for both banks  $i$  and  $j$ , the expected social cost of bank failures—that the

regulator cares about but individual banks do not—also increases with bank leverage. Thus, the regulatory optimum drops below the private optimum.

We now interpret the two conditions in the proposition. When  $\beta$  is low, (i.e.,  $\beta \leq 0.5$ ), the social value of creditors learning about the asset-value impairment shock by observing the liquidations of other banks is also low; since the likelihood of the asset-value impairment shock is low, so is the value of learning about it. Since higher bank leverage leads to a higher liquidation probability, the social value of higher leverage declines as the value of learning about the systematic shock through liquidations declines due to a reduction in  $\beta$ . The inefficiency associated with contagious liquidations remains unaffected, however. That is, since the privately-optimal leverage choice of a bank does not internalize the inefficient contagious liquidations of other banks induced by its own leverage, the bank levers up more than is desirable from the regulator's (social efficiency) viewpoint, regardless of  $N_2$ , the social cost of bank failures. When  $N_2$  is high enough, however, the socially optimal leverage falls below the private optimum regardless of  $\beta$ . That is, the value of creditors learning about asset-value impairment through the actions of other creditors is swamped by the social costs of bank failures.

This is the “dark” side of leverage-based liquidity creation by individual banks. Having leverage at the bank level is a desirable objective from a micro-prudential standpoint but socially costly due to its perverse implications for macro-prudential outcomes. Formally, it is the case that socially-optimal leverage  $\hat{F}$  has the same comparative statics properties as for the privately-optimal leverage  $F^0$  in Corollary 2. Nevertheless, what matters for efficiency is the difference between the two ( $F^0 - \hat{F}$ ) and this difference has comparative statics similar to those in Corollary 2. That is, the difference between the privately optimal leverage  $F^0$  and the socially optimal leverage  $\hat{F}$  is increasing in the manager's private benefit,  $B$ , and the likelihood,  $\gamma$ , that the systematic state is visible to bank creditors, and decreasing in the probability,  $\beta$ , of systematic asset-value impairment shock, and the managerial discount factor,  $\rho$ .

We now discuss the comparative statics generated by the example above.<sup>24</sup> Consider, for instance, the effect of private benefit parameter,  $B$ . This makes leverage privately more attractive, but as each bank increases its leverage to minimize on compensation costs due to equity financing (which are higher for higher  $B$ ), it ignores the externality through contagion of increasing leverage on the other bank. A decrease in the discount factor of the manager on incentive-based compensation produces a similar effect. And, an increase in the visibility of the systematic asset shock to creditors – that is, an increase in the information generation capacity of creditors – makes debt privately more attractive, but the private choice again ignores the contagion-based externality imposed on the other bank.

**Capital requirements with no bailouts:** Since private incentives to lever up banks are in general inefficient, there is justification for *ex-ante* regulatory capital requirements that limit bank leverage to a maximum of  $\hat{F}$ . It is important to point out that absent bailouts, the optimal capital level of the banks in this case is not 100%, or conversely leverage is not zero. This is because just as leverage financing of banks in the model has deadweight costs for the system due to inefficient contagion from one bank's liquidation to the other bank's liquidation and the social costs of bank failures, there is also the deadweight cost of equity-based financing because equity financing requires incentivizing managers through performance-based compensation that entails a higher overall compensation cost to the firm as managers dis-

<sup>23</sup> Bagehot's (1873) also recommended that the LOLR should not lend to an insolvent bank, i.e., it should be concerned with resolving illiquidity problems rather than insolvency problems. In our model, when the regulator bails out a bank that has been hit with an asset-value-impairment shock, it is assisting a potentially insolvent bank. However, it is an action that prevents contagion and protects the payment system, something that Bagehot's (1873) endorsed.

<sup>24</sup> These comparative statics on inefficiency of privately optimal leverage are difficult to prove analytically but illustrated graphically in Fig. 3 in Appendix B for a numerical example.

count incentive-based compensation more than cash. Another way of seeing this is that in the off-equilibrium calculation where the bank is entirely financed by outside equity, the compensation required to be paid to the bank manager to ensure correct incentives may be so high that the bank may have little ex-ante liquidity in the first place, and it may not be economically viable. Bank leverage, in contrast, has the benefit of disciplining the banker in a more incentive-efficient manner, implying that there is some benefit to bank leverage even in the socially-optimal case.

### Case 2. Unconditional Bailouts: Loss of market discipline role of debt

Given that contagious liquidations are inefficient, there may also be a role for regulatory intervention in the form of a bailout of banks threatened by liquidation. In particular, if the regulator observes a threatened liquidation that may trigger a contagion of liquidation on the other banks, it steps in and buys out the creditors of threatened banks. The purpose of the following discussion is to examine the consequences of such intervention. We begin by assuming that the regulator operates under a serious informational constraint – it does not observe the  $x$  of any bank or the realization of  $\xi$ . Hence, it *cannot* distinguish between liquidations based on the realization of  $x$  observed by the bank's own creditors and those based on the observed liquidations of *other* banks. In this case, if  $N_2$  is large enough (and as assumed greater than the cost of bailing out both banks  $C_2$ ), the regulator will find it ex-post optimal to pursue unconditional bailouts of all banks threatened with liquidations.

The problem with a more limited regulatory resolution of threatened banks—one in which only *some* banks are bailed out—is that unless the regulator backstops creditors, information about there being potentially an adverse asset-value shock is likely to leak out. In this case, the bailout by the regulator serves no purpose at all since all other banks' creditors will infer that a liquidation was imminent, and contagion will set in.<sup>25</sup> Thus, unconditional bailouts of all banks become attractive for the regulator. Knowing this, creditors who can threaten liquidation at  $t=1$  will demand that the regulator pay them  $F - x$  in full after they have collected the date-1 cash flow  $x$ . This means that creditors can threaten liquidation at  $t=1$  in every state and receive  $F - x$  in addition to  $x$ . Anticipating this, they would have no reason to engage in privately-costly monitoring, and all the market discipline of leverage is lost. Of course, the *ex-ante* pricing of leverage will reflect the fact that it is riskless, so creditors will not ex ante get a “free lunch”. However, the entire burden of disciplining the manager now falls on the equity-based compensation contract and the amount of bank leverage is irrelevant. The value of the bank then is:

$$V^H = E(x) + qH \int_0^{x_{\max}} \left( \frac{x}{x_{\max}} \right) dx - \bar{W} - [1 - \rho]\theta^* \left\{ \int_0^{x_{\max}} \left( \frac{x}{x_{\max}} \right) dx + qH \int_0^{x_{\max}} \left( \frac{x}{x_{\max}} \right) dx \right\} \quad (32)$$

We now have the following result:

**Proposition 5** (Capital structure and liquidity creation with unconditional regulatory bailouts). *When the regulator unconditionally bails out banks at  $t = 1$  and prevents liquidations, the bank's capital structure becomes irrelevant, and for  $\kappa > 0$  sufficiently small, the bank's ex-ante liquidity is lower with the regulatory intervention than without.*

The intuition for capital structure irrelevance is straightforward. If we remove the disciplining role of debt and make interim liq-

uidations impossible, then we have neither a benefit nor a cost associated with leverage.<sup>26</sup> The reason why the regulator causes the bank to have lower ex-ante liquidity is that the disciplining role of leverage is important for enhancing the bank's liquidity ex ante. Note, however, that this is not a total loss of liquidity as in some models where the absence of the disciplining role of leverage means that the loan financed by the bank becomes completely illiquid. The equity compensation-based incentives do provide ex-ante liquidity, but this is not as much as is available with the optimal combination of debt and equity in the absence of the regulator.<sup>27</sup>

This is somewhat of a paradox. The role of the regulator is to *increase* the liquidity in the system. And yet the presence of the regulator *reduces* the ex-ante liquidity of banks. This exposes a fundamental tension between the macro-prudential goal of eliminating large-scale failures via contagion and the micro-prudential goal of ensuring market discipline as a complement to regulatory oversight. In effect, the “price” of having a system flush with ex-post liquidity provided by the regulator is lower ex-ante liquidity. Thus, our analysis supports [Bagehot's \(1873\)](#) assertion that the LOLR should not engage in unconditional bailouts, which include those that occur even when the payment system is not threatened.

**Capital requirement with unconditional bailouts:** Interestingly, in the case of unconditional bailouts, the optimal capital requirement is to require that banks have no leverage whatsoever. To see this, note that the regulatory objective (29) in this case takes the form  $V_i^H(F_i, F_j) + V_j^H(F_i, F_j) - [1 - \delta_0]C_2$ .

As we discussed above,  $V^H$  does not depend on the leverage of either bank. However, the likelihood of joint failures is increasing in the leverage of each bank. It follows then that the optimal capital requirement is to set  $F$  to zero for both banks, i.e., the optimal capital requirement is 100% equity financing of banks. Such a requirement has recently been proposed by [Admati et al. \(2013\)](#) as a possible way of regulating bank capital. Our result clarifies that the case for 100% equity financing of banks as a capital requirement relies crucially on leverage playing no economically useful role, which in turn, arises when the bailout policy is to bail out banks in all states of the world so that all market discipline role of debt is destroyed and incentive provision for bankers must occur all through equity incentives. The capital requirement, however, cannot restore the loss of bank liquidity arising from the lack of market discipline from debt.

### Case 3. The regulator with expanded information access: Conditional liquidations

We now consider the case in which the regulator can, at a cost  $\psi > 0$ , obtain with probability 1 information about the systematic asset-value-impairment shock at  $t = 1$ . One can interpret this as the regulator setting up a new regulatory body like the Financial Stability Oversight Council (FSOC) and the Office for Financial Research (OFR), as required in the United States following the Dodd-Frank Act, in order to gather information germane to systemic risk and monitor risk across different parts of the economy. We continue to assume that the regulator *cannot* observe the  $x$  of any bank. The following result indicates that a regulatory policy of selective intervention that tolerates some bank failures can achieve the goal of eliminating contagion without distorting ex-ante asset

<sup>26</sup> Now, any distortion in favor of debt such as tax deductibility of interest rate payments can lead the financial sector to lever up in a significant manner. Also, as argued by [Acharya and Yorulmazer \(2007\)](#), [Acharya, Mehran and Thakor \(2016\)](#), and [Farhi and Tirole \(2012\)](#), there would be an incentive to increase the systematic risk of projects, if that were a choice variable in our model, and banks would prefer to fund these correlated projects with leverage to “loot” the regulator/taxpayers (assuming bank equity is not bailed out in case of joint failures).

<sup>27</sup> Because equity provides some discipline, banks do not fail with probability 1. Hence, the probability of an unconditional regulatory bailout is positive, but not 1.

<sup>25</sup> With dispersed creditors, it may be difficult to prevent this information from leaking out.

and leverage decisions away from the equilibrium without LOLR intervention. Such a policy may represent an optimal policy for the regulator if  $N_1$ , the cost of a single bank failing is relatively low, but  $N_2$ , the social cost of both banks failing is very high. In general, such a policy will be optimal when the regulator perceives a low social cost associated with a few idiosyncratic bank failures, but a high social cost associated with a meltdown of the whole system. This is indeed our working assumption in assuming that  $C_2 < N_2$ .

**Proposition 6** (Regulatory Bailout Policy that Preserves Market Discipline). *Suppose the regulator pre-commits to an intervention policy such that*

- (i) *only if the regulator has learned at  $t = 1$  that bank asset values are systematically impaired, then any bank whose creditors threaten liquidation is bailed out by the regulator promising the bank's creditors in private negotiations that they will be paid in full at  $t = 2$  if they allow the bank to continue; and,*
- (ii) *if the regulator has learned that there is no asset value impairment, then any bank whose creditors threaten liquidation is allowed to be liquidated at  $t = 1$ .*

*Under this intervention policy, and assuming that the bailout negotiation in (i) is secret so that the creditors of no other banks learn that particular bank was bailed out, the probability of contagion is driven to zero, and no bank's creditors liquidate the bank when they observe another bank being liquidated. Moreover, each bank chooses leverage*

$$\hat{F}^* = \frac{x_{\max}}{\{[1 - \lambda^2][qH^0 - L] \{ [1 - \rho]\theta^*\}^{-1} - [qH^0 - 1]\}} \quad (33)$$

where

$$H^0 \equiv \beta H^+ + [1 - \beta]H^- \quad (34)$$

*and also chooses the good loan (unlike in Proposition 5). The market discipline of both debt and equity are preserved as in the case in which the regulator does not bail out any banks and there is no asset-value impairment shock.*

This proposition says that the regulator can eliminate systemic risk by guaranteeing that any bank that is on the brink of being liquidated due to the systematic shock will be bailed out by the regulator. This can either be a standard bailout or something akin to the Troubled Asset Relief Program (TARP), wherein the government steps in and agrees to purchase the (devalued) assets (or undervalued equity) of banks at a price exceeding market value. Of course, implementing such a scheme requires that the regulator be able to have access to information about the systematic shock, and this may prove to be quite expensive in practice (high  $\psi$ ). It is also crucial that the regulator's bailout is a secret negotiation with the bank in question. This means that even though the systemic asset value impairment shock may have been realized, the regulator will permit unassisted continuation of banks whose creditors do not threaten liquidation.

The other part of this intervention is that the regulator avoids any bailout if the creditors' liquidation threat does not coincide with a systematic impairment in bank asset values. That is, any liquidation due to an  $x$  realization for individual bank being in the liquidation range is allowed to proceed. Note, however, that common knowledge of such intervention policy means that any liquidation that is publicly observed noiselessly reveals that asset values are *not* systematically impaired, so there is no contagion. Moreover, because such liquidations are allowed to occur, all the market discipline of debt and equity that was present in the case without the regulator and the systematic shock is resurrected. This is why  $\hat{F}^*$  in (33) has the same functional form as the  $F^*$  in (12); the only difference is that  $H$  is replaced by  $H^0$ .

The regulator thus avoids contagion by giving banks a put option on the value of their assets, but this option has value only if it is exercised at  $t = 1$ . If bank creditors do not threaten liquidation at  $t = 1$  (because they do not receive a signal that asset values have declined), but there has actually been a decline in asset values, then their loss at  $t = 2$  will not be covered by the regulator. This suggests that it might pay for the creditors to threaten liquidation whenever  $x \in [x_{\min}, \lambda F]$ , even when they have not received an asset-value impairment shock. If the regulator agrees to bail out the bank (because the systematic shock has, in fact, occurred), then the liquidation threat succeeds from the standpoint of creditors. If not (because asset values are not truly impaired), then creditors can withdraw their liquidation threat. That is, there may be "frivolous" liquidation threats in order to "game" the regulator. To avoid this, the regulator can stipulate penalties on creditors for liquidation threats that are not carried out in the event the regulator refuses to bail out. Another way that frivolous threats may be ruled out is if there are fixed costs to liquidation that are incurred ex post by creditors.

Avoiding contagion in this manner and simultaneously restoring market discipline comes at an ex-post cost as in the benchmark model. Specifically, in order to avoid contagion but preserve market discipline, the regulator prevents bailouts banks when the systematic shock indicates asset-value impairment, and permits inefficient liquidations based on idiosyncratic ( $x$ ) risk to proceed. There may be time-inconsistency issues with the regulator allowing such inefficient liquidations (Acharya and Yorulmazer (2007), Farhi and Tirole (2012)), unless its intervention policy such as in Proposition 6 is based on rules that have commitment. Hence, our result in Proposition 6 can be viewed as merely characterizing a minimum set of information requirements for the regulator to have a possible chance of restoring ex-ante efficiency.

**Capital requirement with conditional bailout policy:** In Proposition 6, we have characterized the bank's private optimum in response to the regulator's bailout policy. We could also analyze the regulator's (socially-optimal) capital requirement. Note, however, that a bank's leverage no longer has any contagion effects. Hence, as explained in the proof of Proposition 6 in Appendix A, each bank's valuation is given by  $V^{III}$ , which is the same as  $V$  in (10) with  $H$  replaced by  $H^0$ . In particular,  $V_i^{III}$  depends only on the leverage of bank  $i$  and not on the leverage of bank  $j$ . Then, the ex-ante social objective function is given by

$$V_i^{III}(F_i) + V_j^{III}(F_j) - [\delta^j(1 - \delta^i) + \delta^i(1 - \delta^j)]N_1 - \delta^i\delta^jN_2 - 2\beta\gamma(1 - \gamma)C_1 - \beta\gamma^2C_2 - \psi \quad (35)$$

which captures the fact that (i) idiosyncratic bank failures do occur with this conditional bailout policy; (ii) joint failures may also arise due to idiosyncratic adverse shocks hitting both banks simultaneously; (iii) bank failures due to systematic asset-impairment shocks are avoided by the regulator incurring bailout costs; and, finally (iv) the regulator incurs costs of generating information about the systematic asset shock.

The social optimum of bank leverage is thus lower than the privately-optimal leverage level,  $\hat{F}^*$ , because banks do not internalize the social costs of their own failures, represented by  $N_n$ , and the bailout costs,  $C_n$ . It can also be shown (proof available upon request) that as long as the joint-failures cost  $N_2$  is sufficiently large, the socially optimal leverage in the case of conditional bailouts exceeds that under the first case of no bailouts.<sup>28</sup> Intuitively, by generating information on the systematic asset shocks and avoiding costly joint failures, the conditional bailout policy allows bank leverage, and in turn, bank liquidity, to be higher.

<sup>28</sup> Formally, for given choice of bank leverage ( $F$ 's), the social costs of failure under the case of no bailouts exceed those under the case of conditional bailouts.

In the context of the current regulatory landscape in the U.S., the regulator here is a combination of the Financial Stability Oversight Council (FSOC) and a “Resolution Authority” that can determine how to intervene in the event of bank failures. Indeed, an interesting implication of the analysis is that there is an important interaction between these two regulatory functions. The information gathered by the FSOC can be useful to the Resolution Authority in permitting a *larger* number of bank liquidations via selective intervention, and by doing so it may prevent systemic crises and allow *ex-ante* bank leverage and liquidity to be regulated at higher.

## 6. Conclusion

In this paper, we re-examined the role of bank leverage as an instrument of liquidity creation. We exposed a fundamental tension between the micro-prudential goal of encouraging the market discipline of banks via greater uninsured leverage in their capital structure and the macro-prudential goal of containing systemic risk. While higher bank leverage creates stronger creditor discipline at the *individual* bank level, it leads to greater systemic risk induced by contagious runs when creditors liquidate banks. To the extent that such contagion threatens the entire financial system and hence jeopardizes the payment system, it invites *ex-post* regulatory intervention to bail out “failing” banks from being liquidated by creditors and thereby to maintain the interim liquidity and continuity of banks.

The consequences of this regulatory intervention depend on the regulator’s information and the nature of the intervention. When the regulator has no information about whether systematic asset-value impairment has occurred, it has two choices. It can precommit to never bail out any bank. But even in this case, the socially optimal bank capital is above the private optimum under plausible conditions and a regulatory capital requirement is needed. The regulator’s other choice is to bail out banks. Due to the regulator’s information constraints, the intervention is unconditional, so the disciplining role of bank leverage is lost, and *ex-ante* bank liquidity actually declines. In fact, the more vigilant the regulator is in reacting to early warnings delivered via market signals by intervening with bailouts of failing banks, the worse is the problem. Absent its disciplining role, all that bank debt offers is the information externality that leads to contagion. This “dark side” of leverage necessitates arbitrarily high regulatory capital requirements—indeed, bank debt has no social value at all.<sup>29</sup>

We show that when the regulator generates its own information about the systematic shock—rather than relying on market signals—and *conditions* bailouts on this information, contagion can be eliminated without sacrificing debt discipline. There is more *ex ante* liquidity, and the regulatory capital requirement is lower than even in the case in which the regulator credibly pre-commits to no bailouts.

In addition to addressing policy-relevant issues, our analysis also generates a few empirical predictions. First, the probability that a bank will be liquidated is higher not only when the bank is more highly levered, but also when *other* banks holding similar asset portfolios are more highly levered. Thus, there will be an “industry-wide” leverage effect that will be felt by individual banks. Second, banks will be more highly levered when managerial private benefits are higher and systematic shocks to asset values are more visible to creditors but less likely. And third, banks

create less liquidity in markets in which regulators engage in more unconditional bailouts.

In terms of future research, an interesting extension of our analysis will be to examine the role of the information generated by stock prices or CDs spreads. While the majority of U.S. banks are not traded, the issue is germane for large, traded banks. With these additional market signals, information about systematic shocks is likely to be more readily available to market participants than in our model. Our analysis implies, however, that a resolute commitment by the regulator to bail out banks threatened by a systematic shock can stanch the likelihood of contagion even in this case.<sup>30</sup>

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## Appendix A

**Proof of Lemma 1.** Obvious from the discussion in the text.  $\square$

**Proof of Lemma 2.** First, let us consider the intervention policy of creditors. If the creditors intervene, they can force the bank manager to invest in the good loan and the creditors’ date-2 payoff, after having been paid  $x$  at date-1, is  $q[F - x] - \kappa$ , taking into account the investigation cost. If creditors do not intervene, the manager will select the private-benefit loan, and the creditors’ date-2 payoff will be  $p[F - x]$ . Thus, intervention is optimal for creditors if:

$$q[F - x] - \kappa > p[F - x] \text{ or } x < F - \kappa[\Delta]^{-1}. \quad (\text{A-1})$$

Now, we turn to the liquidation/continuation decision after having invested  $\kappa$ . We compare (5) and (6). Since  $L < qH$ , there are three cases to consider: (i)  $F - x < Lx$ ; (ii)  $Lx < F - x < Hx$ ; and (iii)  $F - x > Hx$ .

**Case. (i):**  $F - x < Lx$ : In this region,  $x > F/[1 + L]$ . Thus, the liquidation payoff to creditors is  $F - x$ . The continuation payoff is  $q[F - x] < F - x$ . Hence, the creditors liquidate the bank.

**Case. (ii):**  $Lx < F - x < Hx$ : In this case,  $Lx + x < F$ , which means  $x < F/[1 + L]$ . Moreover,  $F < Hx + x$ , which means  $x > F/[1 + H]$ . So,  $F/[1 + H] < x < F/[1 + L]$ . The liquidation payoff to creditors is

<sup>30</sup> In our analysis, systemic risk issues arise due to commonality in the asset holdings of banks. Such correlated portfolio choices have been observed in many crises. For example, in the 2007–09 subprime crisis, the commonality of asset portfolios was in the form of real estate loans. A somewhat cynical political economy view is that bailouts of banks in the event of a systemic meltdown was a way for the government to induce banks to correlate their asset choices in real estate lending so that *ex post* bailouts can occur, thereby providing a subsidy for real estate lending, something that serves political goals. We thank Charlie Calomiris for this insight. We do not mean to suggest, however, that real-estate lending should not be encouraged by the government. There may be many economic benefits from this lending that are not reflected in our analysis. And of course, real estate lending is not the only example of correlated lending by banks. There are numerous other examples, such as lending to oil companies. These examples often occur when lending to a particular sector has done well for a long time (see, for example, Thakor (2015)).

<sup>29</sup> All of this assumes that the bank’s uninsured creditors generate monitoring-relevant information that regulators do not. One reason for this may be that these creditors have “skin in the game” and are actively trading in a variety of securities and markets, so they obtain market signals that may be unavailable to regulators who focus primarily on banks.

$Lx$ , whereas the continuation payoff is  $q[F - x]$ . Creditors liquidate whenever:  $Lx > q[F - x]$  or  $x > \lambda F$ , where  $\lambda \equiv \frac{q}{q+L}$ .

Creditors continue if  $x \leq qF[q + L]^{-1}$ .

**Case.** (iii):  $F - x > Hx$ : In this region,  $x < F/[1 + H]$ . The liquidation payoff of creditors is  $\min(Lx, F - x) = Lx$ . Since  $x + xH < F$  implies that  $x + xL < F$ . The continuation payoff of creditors is  $qHx$ . Since  $qH > L$ , the creditors continue.

Finally, since  $qH > L$ , all liquidation is inefficient.  $\square$

**Proof of Proposition 1.** Using (7), (8) and (9), we can write (10) as:

$$\begin{aligned} V(F) &= E(x) + qHE(x) - qH \int_{\lambda F}^F \left(\frac{x}{x_{\max}}\right) dx + \int_{\lambda F}^F \left(\frac{Lx}{x_{\max}}\right) dx \\ &\quad - \theta^* \int_x^F [(x - F) + qHx]g(x)dx - \bar{W} \\ &\quad + \rho\theta^* \int_x^F [(x - F) + qHx]g(x)dx \\ &= [1 + qH]E(x) - qH \int_{\lambda F}^F \left(\frac{x}{x_{\max}}\right) dx + \int_{\lambda F}^F \left(\frac{Lx}{x_{\max}}\right) dx \\ &\quad - \bar{W} - [1 - \rho]\theta^* \left\{ \int_F^{x_{\max}} \left(\frac{x - F}{x_{\max}}\right) dx \right. \\ &\quad \left. + qH \int_F^{x_{\max}} \left(\frac{x}{x_{\max}}\right) dx \right\} \\ &= [1 + qH]E(x) - \frac{[qH - L][1 - \lambda^2]F^2}{2x_{\max}} - \bar{W} \\ &\quad - [1 - \rho]\theta^* \left\{ \frac{[1 + qH][x_{\max}^2 - F^2]}{2x_{\max}} - \frac{F[x_{\max} - F]}{x_{\max}} \right\}. \quad (\text{A-2}) \end{aligned}$$

The optimal  $F$ , say  $F^*$ , must satisfy the first-order condition:

$$-[qH - L]F^*[1 - \lambda^2] + [1 - \rho]\theta^* \{ [1 + qH]F^* + x_{\max} - 2F^* \} = 0. \quad (\text{A-3})$$

Rearranging (A-3) yields (12).

Next, we verify the second-order condition for a unique global maximum:

$$-[qH - L][1 - \lambda^2] + [1 - \rho]\theta^*[qH - 1] < 0, \quad (\text{A-4})$$

that is satisfied under our maintained assumptions.

Now let us see what conditions are needed for  $F^* \in (0, x_{\max})$ . For  $F^* < x_{\max}$ , we need:

$$\frac{[1 - \lambda^2][qH - L]}{[1 - \rho]\theta^*} - [qH - 1] > 1. \quad (\text{A-5})$$

Substituting for  $\theta^*$  from (4) and rearranging yields that we require that

$$B < \frac{\Delta[1 - \lambda^2][qH - L]}{q[1 - \rho]} \equiv \bar{B}. \quad (\text{A-6})$$

To ensure that  $F^* > 0$ , we need  $\frac{[1 - \lambda^2][qH - L]}{[1 - \rho]\theta^*} - [qH - 1] > 0$ , which is satisfied for  $B < \bar{B}$  (because then (A-6) holds). Moreover, it is also clear that since (A-6) holds, the inequality in (A-5) also holds.  $\square$

**Proof of Corollary 1.** Note that (12) shows that  $\partial F^*/\partial \theta^* > 0$ . Moreover, from (4) we know that  $\partial \theta^*/\partial B > 0$ . Thus,  $\partial F^*/\partial B > 0$ . From (12) it also follows immediately that  $\partial F^*/\partial \rho < 0$ .  $\square$

**Proof of Proposition 2.** The (unconditional) ex-ante probability of liquidation by bank  $i$ 's creditors (see (23)) is

$$PRB_i \equiv 1 - \delta_0^i = 1 - [1 - \delta^j][1 - \delta^i]\{\beta[1 - \gamma]^2 + 1 - \beta\}.$$

where we have explicitly distinguished between  $\delta^j$  and  $\delta^i$ . thus,

$$\frac{\partial PRB_i}{\partial F_i} = -\frac{[1 - \delta^j][1 - \delta^i]}{>0}$$

Moreover,  $\partial \delta^j/\partial F_j = [1 - \lambda]/x_{\max} > 0$ . Thus, it follows that  $\partial PRB_i/\partial F_i > 0$ . Now  $\partial PRB_i/\partial \delta^j = -[1 - \delta^i][1 - \delta^j] > 0$ .

Since  $\partial \delta^j/\partial F_j = [1 - \lambda]/x_{\max} > 0$ , it follows that  $\partial PRB_i/\partial F_j > 0$ .  $\square$

**Proof of Lemma 3.** Differentiating  $\tilde{B}(F_j)$  in (26).

$$\begin{aligned} \frac{\partial \tilde{B}(F_j)}{\partial \delta^j} &= -\Delta \lambda^2 \left\{ \frac{\partial \delta_2}{\partial \delta^j} [H^+ - L] - \frac{\partial \delta_1}{\partial \delta^j} [L - H^-] \right\} \\ &= -\Delta \lambda^2 \left\{ \frac{-\beta[1 - \gamma]^2 [H^+ - L]}{+[1 - \beta][1 - \gamma][L - H^-]} \right\} \\ &= -\Delta \lambda^2 [H^+ - L][1 - \gamma][-\beta[1 - \gamma] + 1 - \beta] \end{aligned}$$

where the last step follows from  $H^+ - L = L - H^- < 0$  since  $\beta \leq 0.5$ .  $\square$

**Proof of Proposition 3.** Using (7), (8) and (9), we can write (23) as:

$$\begin{aligned} V(F) &= E(x) + [\delta_1 H^- + \delta_2 H^+]q \int_0^{\lambda F} \left(\frac{x}{x_{\max}}\right) dx \\ &\quad + \int_{\lambda F}^F \left(\frac{Lx}{x_{\max}}\right) dx + [1 - \delta_1 - \delta_2]L \int_0^{\lambda F} \left(\frac{x}{x_{\max}}\right) dx \\ &\quad + qH \int_F^{x_{\max}} \left(\frac{x}{x_{\max}}\right) dx - \bar{W} \\ &\quad - [1 - \rho]\theta^* \left\{ \int_F^{x_{\max}} \left(\frac{x - F}{x_{\max}}\right) dx + qH \int_F^{x_{\max}} \left(\frac{x}{x_{\max}}\right) dx \right\}. \quad (\text{A-7}) \end{aligned}$$

Simplifying and rearranging terms, we can write (A-7) as:

$$\begin{aligned} V(F) &= [-F^2/2x_{\max}]\{qH - [1 - \rho]\theta^*[qH - 1] \\ &\quad - [L + \lambda^2\{\delta_2[H^+ - L] - \delta_1[L - H^-]\}]\} \\ &\quad + [1 - \rho]\theta^*F + \text{constant}, \quad (\text{A-8}) \end{aligned}$$

where the *constant* includes all the terms that do not contain  $F$ . The first-order condition for the optimal best response of bank  $i$ ,  $F_i^0(F_j^0)$ , is (suppressing the argument  $F_j^0$ ):

$$\begin{aligned} -F_i^0\{qH - [1 - \rho]\theta^*[qH - 1] \\ - [L + \lambda^2\{\delta_2^j[H^+ - L] - \delta_1^j[L - H^-]\}]\} \\ + [1 - \rho]\theta^*x_{\max} = 0. \quad (\text{A-9}) \end{aligned}$$

Rearranging (A-9) and simplifying yields (27).

The second-order condition for a maximum is:

$$-\{qH - [1 - \rho]\theta^*[qH - 1] - [L + \lambda^2\{\delta_2^j[H^+ - L] - \delta_1^j[L - H^-]\}]\} < 0. \quad (\text{A-10})$$

To ensure  $F_i^0 < x_{\max}$ , (27) indicates that we need

$$qH > [1 - \rho]\theta^*qH + L + \lambda^2\{\delta_2^j[H^+ - L] - \delta_1^j[L - H^-]\}. \quad (\text{A-11})$$

Using (4) to substitute for  $\theta^*$  and rearranging gives us:

$$B < \frac{\Delta[qH - L - \lambda^2\{\delta_2[H^+ - L] - \delta_1[L - H^-]\}]}{[1 - \rho]q} \quad (\text{A-12})$$

The right-hand side (RHS) of (A-12) is  $\hat{B}$  if we set  $\delta_1 = \bar{\delta}_1$  and  $\delta_2 = \bar{\delta}_2$ . Moreover,  $\hat{B} \leq \text{RHS of (A-12)}$ . Thus, setting  $B < \hat{B}$  ensures that (A-12) will hold.

Note that as long as  $B < \hat{B}$ , the second-order condition (A-10) will also be satisfied. Moreover, satisfaction of (A-10) also guarantees that  $F_i^0 > 0$ . Thus,  $F_i^0 \in (0, x_{\max})$ .

To obtain (28), note that with symmetry across banks  $i$  and  $j$ , both banks have exactly the same best response conditional on a given leverage choice by the other bank. Substituting  $F_j^0(F_i^0) = F_i^0(F_j^0)$  in (27), we can write

$$F^0 = \frac{1}{a + bF^0}, \tag{A-13}$$

where  $a$  and  $b$  are defined in Proposition 3. Solving (A-13) as a quadratic equation yields (28). Note that we need  $b > 0$ , which is true if  $\beta < [2 - \gamma]^{-1}$ . This is guaranteed by  $\beta \leq 0.5$ .  $\square$

**Proof of Corollary 2.** Write  $F_i^0(F_j^0)$  as

$$F_i^0(F_j^0) = \frac{x_{\max}}{\left\{ \frac{qH - [L + \lambda^2 \{ \delta_2^j [H^+ - L] - \delta_1^i [L - H^-] \}]}{[1 - \rho]^{\theta^*}} - [qH - 1] \right\}}. \tag{A-14}$$

It is clear that, holding  $F_j^0$  fixed,  $\partial F_i^0(F_j^0) / \partial \theta^* > 0$ . Since  $\partial \theta^* / \partial B > 0$ , it follows that  $\partial F_i^0(F_j^0) / \partial B > 0$ . That is, each bank's best response is increasing in its own manager's  $B$ . In a symmetric Nash equilibrium therefore,  $\partial F^0 / \partial \theta^* > 0$ . To establish the sign of  $\partial F^0 / \partial \beta$ , note that the sign of  $\partial F_i^0(F_j^0) / \partial \beta$  depends solely on the sign of  $\partial A / \partial \beta$  where  $A \equiv \delta_2 [H^+ - L] - \delta_1 [L - H^-]$ . Now,  $\partial A / \partial \beta = -[H^+ - L][\gamma + \{1 - \gamma\}\{1 - \delta\}] - [1 - \delta][1 - \gamma]^2 [L - H^-] < 0$ .

Since  $\partial F_i^0(F_j^0) / \partial A > 0$ , we have  $\partial F_i^0(F_j^0) / \partial \beta < 0$ . In a symmetric Nash equilibrium therefore,  $\partial F^0 / \partial \beta < 0$ . Moreover, it can also be verified that  $\partial F_i^0(F_j^0) / \partial \rho < 0$  and  $\partial F^0 / \partial \rho < 0$ .  $\square$

**Proof of Proposition 4.** The  $\hat{F}_i$  that maximizes  $V_i + V_j$  is the one that maximizes:

$$\begin{aligned} & -\{F_j^2 D(F_j) / 2x_{\max}\} + [1 - \rho]\theta_i^* F_i - [1 - \delta^j][1 - \delta^i]N_2 + \text{constant}_i \\ & -\{F_j^2 D(F_i) / 2x_{\max}\} + [1 - \rho]\theta_j^* F_j - [1 - \delta^j][1 - \delta^i]N_2 + \text{constant}_j, \end{aligned} \tag{A-15}$$

where

$$\begin{aligned} D(F_j) & \equiv qH - [1 - \rho]\theta_i^* [qH - 1] \\ & \quad - [L + \lambda^2 \{ \delta_2(F_j) - [H^+ - L] - \delta_1(F_j)[L - H^-] \}], \\ D(F_i) & \equiv qH - [1 - \rho]\theta_j^* [qH - 1] \\ & \quad - [L + \lambda^2 \{ \delta_2(F_i)[H^+ - L] - \delta_1(F_i)[L - H^-] \}]. \end{aligned}$$

The first-order condition for the regulator's optimal choice of  $\hat{F}_i$ , given  $F_j$ , is:

$$\begin{aligned} & -\{\hat{F}_i D(F_j) / x_{\max}\} + [1 - \rho]\theta_i^* + \{F_j^2 / 2x_{\max}\} \{ \lambda^2 [\partial A_i / \partial \hat{F}_i] \} \\ & - J(F_j)N_2 = 0 \end{aligned} \tag{A-16}$$

where

$$A_i \equiv \delta_2(\hat{F}_i)[H^+ - L] - \delta_1(\hat{F}_i)[L - H^-] \tag{A-17}$$

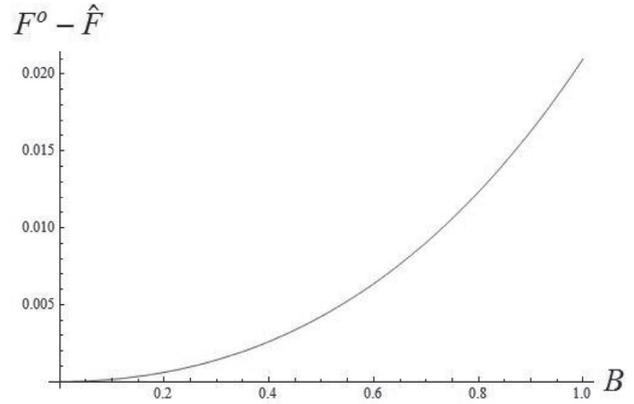
$$J(F_j) \equiv -\{ [1 - \delta^j][1 - \lambda] / x_{\max} \} \{ \beta [1 - \gamma^2] + [1 - \beta] \} \tag{A-18}$$

Rearranging (A-16) yields:

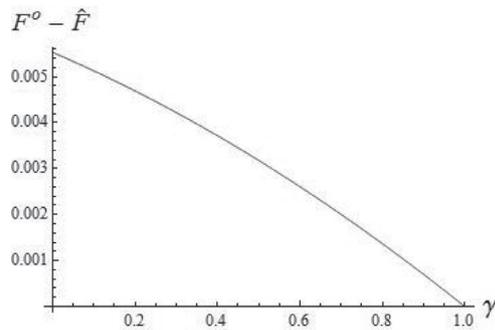
$$\hat{F}_i = \frac{[1 - \rho]\theta_i^* x_{\max} + [F_j^2 / 2][\lambda^2 [\partial A_i / \partial \hat{F}_i]] - J(F_j)N_2}{D(F_j)}. \tag{A-19}$$

Comparing (A-20) with (27), we see that  $\partial A_i / \partial \hat{F}_i < 0$  is sufficient for  $\hat{F}_i < F_i^0$ . Now, using  $H^+ - L = L - H^-$ , we can write  $A_i$  as:

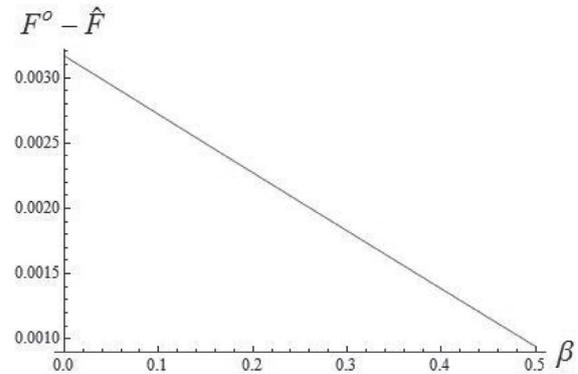
A. As a Function of the Private Benefit B



B. As a function of  $\gamma$ , the Visibility of the Systematic Shock to Creditors



C. As a Function of  $\beta$ , the Probability of the Systematic Shock



D. As a Function of the Manager's Discount Factor,  $\rho$ .

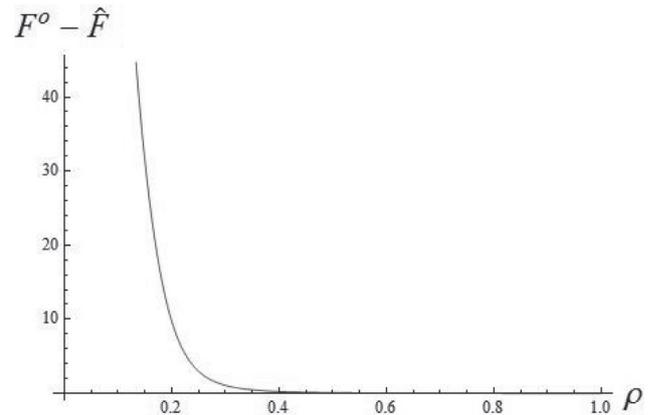


Fig. 3. The Difference Between the Privately Optimal Leverage and the Socially Optimal Leverage.

$$A_i = [H^+ - L][\delta_2(F_i) - \delta_1(F_i)] \\ = [1 - \delta_i][1 - \gamma][1 - \beta - \beta\{1 - \gamma\}] + [1 - \beta]\gamma.$$

Thus,

$$\partial A_i / \partial F_i = -[1 - \gamma][1 - \beta - \beta\{1 - \gamma\}] \frac{\partial \delta_i}{\partial F_i} \\ = -[1 - \gamma][1 - \beta - \beta\{1 - \gamma\}] \frac{[1 - \lambda]}{x_{\max}} \\ < 0 \text{ since } 1 - \beta > \beta\{1 - \gamma\} \text{ due to } \beta \leq 0.5.$$

Thus,  $\hat{F}_i < F_i^0$  regardless of  $N_2$  if  $\beta \leq 0.5$ . However, even if  $N_2$  is sufficiently large, then clearly  $\hat{F}_i < F_i^0$  regardless of  $\beta$ .

To verify that  $\hat{F}_i$  is a unique global maximum, let us examine the second-order condition:

$$-D(F_j)/x_{\max}, \text{ which is clearly negative. } \square$$

**Proof of Proposition 5.** The proof of capital structure irrelevance is obvious (note that (32) is independent of  $F$ ). Comparing the objective functions in (23) and (32), we see that if we ignore  $\kappa$ , then (23) can be made equivalent to (32) by setting  $F=0$ . But the  $F$  that maximizes ex-ante liquidity in (23) is strictly positive. Hence, for  $\kappa > 0$  small enough, the optimized value of  $V(F)$  in (23) exceeds the  $V_{REG}$  in (32).  $\square$

**Proof of Proposition 6.** Since the regulator credibly precommits to bail out any bank that has suffered a systematic asset-value impairment shock, no bank can fail due to this shock. Moreover, since the bailout is secret, no other bank's creditors learn that the asset-value impairment shock has occurred if they did not receive the signal. Finally, since no bank is liquidated due to the asset-value-impairment shock and no liquidations based on  $x$  are prevented, the bank's leverage-choice problem is the same as in (10), except that  $H$  is replaced by  $H^0$ . Hence, (33) is the same as (12) except that  $H$  is replaced by  $H^0$ .  $\square$

## Appendix B. Numerical example

The comparative statics on inefficiency of privately optimal leverage are difficult to prove analytically but illustrated graphically in Fig. 3 for a numerical example (and found to be robust across a range of parameter values we have tried). In the numerical example, we choose as baseline parameters  $q = 3/4$ ,  $p = 1/2$ ,  $B = 0.4$ ,  $\rho = 0.8$ ,  $\gamma = 0.6$ ,  $x_{\max} = 4$ ,  $H = 7/4$ ,  $L = 1$ ,  $H^+ = 1.5$ ,  $H^- = 0.5$ ,  $\beta = 1/8$ ,  $N_2 = 0$ . This is one parameter constellation that ensures that various restrictions assumed throughout the model are all jointly satisfied, except those involving  $N_n$  (because  $\beta$  is assumed low enough for the social optimum to be below the privately optimal leverage anyway).

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