ISSN 1936-5330

The Federal Reserve Bank of Kansas City
Research Working Papers

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March 2011; Revised February 2012

Research Working Papers

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February 6, 2012

Abstract

How to design bank capital requirements when banks can misreport the value of their assets? We show that the answer depends critically on the existence of secondary markets for bank assets. Without secondary markets, capital requirements based on banks' reporting are more socially desirable than a fixed capital requirement if savings on costly bank capital are sufficiently high. Yet with secondary markets, banks can reduce the burden of a fixed requirement by selling their assets. And they have stronger incentive to misreport and game capital requirements based on their reporting, because low quality assets can be sold for elevated prices. We argue that the contemporary banking system, where many bank assets are tradable, can benefit from simpler but harder to game forms of capital regulation.

*The paper is a revised version of the first chapter of my dissertation at the University of Mannheim. I thank Franklin Allen, Thorsten Beck (discussant), Patrick Bolton, Elena Carletti, Denis Gromb, Martin Hellwig, David Martinez-Miera, Chuck Morris, Jorge Ponce, Lev Ratnovski, Rafael Repullo, Javier Suarez, Ernst-Ludwig von Thadden (my PhD supervisor), and participants of seminars at the University of Frankfurt, CEMFI, MPI in Bonn, Riksbank, CERGE-EI, Manchester Business School, Kansas City Fed, Carlos III Madrid, and Riksbank, 2008 Finlawmetrics, EEA/ESEM 2008 and WB/IMF Conference on Risk Analysis for helpful comments. I also thank the German Science Foundation (DFG) and European Corporate Governance Training Network for the financial support during my PhD studies. The views expressed herein are those of the author and do not necessarily represent those of the Federal Reserve Bank of Kansas City or the Federal Reserve System. The paper circulated previously under the title "How To Make the Banks Reveal Their Information."

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"*We have a good deal of comfort about the capital cushions at these firms at the moment.*" - Christopher Cox, then-chairman of the Securities and Exchange Commission, March 11, 2008.

High levels of leverage of investment and commercial banks prior to 2007 have been blamed for the severity of the financial crisis that started in 2007 (IMF (2008), Acharya et al. (2009), CGFS (2009)). Although high levels of leverage might have had many causes, existing regulatory and accounting frameworks tied the capital ratios of investment and commercial banks to their own judgment about the value and the riskiness of their assets.[1] Such frameworks were intended to align bank capital ratios more closely with their exposures and to increase transparency. However, these frameworks may contribute to bank leverage because banks have an incentive to misreport the value and the riskiness of their assets to save on costly equity capital and to shape favorably investors' perception about them.[2] Recently, to limit bank leverage and discretion, the regulators introduced a leverage ratio in the Basel III Accord and standardized haircuts to the SEC's net capital rule for broker-dealers (BCBS (2010), Shapiro (2010)).

In this paper, we explore a bank's incentive to misreport value of its assets and its consequence for bank capital requirements.[3] We do so under two scenarios: without and with a secondary market for bank assets. In the years before the crisis banking systems underwent a dramatic change as tradability of banks' traditional assets (loans) has increased. We argue that the secondary market matters for design of capital requirements for two reasons. First, banks can use its capital more efficiently by selling its assets for which capital requirements are too high from its perspective.[4] Second, if capital requirements depend on banks' reporting, the banks' incentive to misreport is stronger when they can sell their assets than when they keep them. The reason is that the benefit

[1]The 1998 amendment to the Basel I Accord and the 2004 amendment to the SEC's net capital rule addressing market risk as well as the Basel II Accord addressing credit risk allow banks to use their internal risk management models to determine their capital requirements. In accounting, determination of loan loss provisions, treatment of repo transactions, and classification of Level 1-3 assets are the most prominent examples of how the banks can use their judgment to adjust their leverage.

[2]The effect of banks' discretion on their leverage is well documented empirically and anecdotally. Gunther and Moore (2003) use an example of loan loss provisions. Huizinga and Laeven (2010) use Level 1-3 assets. Valukas (2010) describes Lehman Brothers' use of repo 105 and McLean (2011) the MF Global's use of repo-to-maturity. Shapiro (2010) comments on banks' discretion over assumptions in their internal risk management models that lowers capital requirements. Vaughan (2011) reports on the banks' practice of "risk-weighted asset optimization."

[3]Our approach is general enough to encompass the specific case of risk-based capital requirements such as the Basel Accords and SEC's net capital rule, as well as the accounting examples from footnote 1.

[4]Bank capital requirements are a prominent motive for loan sales by banks, and for credit risk transfer in general (see e.g. Acharya, Schnabl and Suarez (2010), Berger and Udell (1993), Demsetz (2000), Drucker and Puri (2009), Duffie (2007), Parlour and Plantin (2008), Saunders and Cornett (2006)).

of misreporting is to sell a low-value asset for a price of a high-value asset when the investors infer the asset values from banks' capital ratios.[5] When banks keep their assets, the only benefit of misreporting is a lower capital requirement. We argue that a modern banking system, in which some bank assets are tradable, can benefit from a fixed capital requirement for all banks, because it does not rely on banks' reporting and the banks can lower the burden from such a capital requirement by selling their assets.

We develop a one-period model with a bank, a social-welfare-maximizing regulator, and outside investors. The bank finances a project using insured deposits and capital that is more costly than deposits.[6] Only the bank knows the value of its project. Capital requirements are needed because of moral hazard problem a la Holmstrom and Tirole (1997): Capital provides the bank with an incentive to exert costly monitoring effort (see e.g. Allen et al. (2011)). Because the cost of monitoring effort and the project's size are the same for each project, the minimum level of capital for which the bank monitors a high-value project is lower than for a low-value project.

Because capital is costly, the regulator would like to use sensitive capital requirements for which the high-value bank (the bank with the high-value project) finances with a lower capital level than the low-value bank (the bank with the low-value project). To gain insight about the project's value, the regulator can inspect the bank after the bank reports the project's value. Inspection is costly and noisy in the sense that the regulator may mistake the low-value project for the high-value one and vice versa. When the regulator's finding is different from what the bank reports, the bank must bear costly recapitalization or, when a secondary market exists, a sale of the project. The regulator chooses the capital requirements for the high- and low-value bank as well as the type of penalty for misreporting and the probability of inspection.

We first consider the case without a secondary market. The low-value bank's benefit from misreporting is a lower capital requirement. The regulator chooses between the following alternatives. The first one is an insensitive capital requirement that is the same for every bank and implies

[5] Dahiya, Puri, and Saunders (2003), Marsh (2006), and Acharya and Johnson (2007) provide empirical evidence of banks' trading on private information on secondary markets.

[6] The results stay the same when the deposits are uninsured so that the model is applicable to commercial and investment banks. Capital is more expensive than deposits due to depositors' preference for liquidity that is provided only with deposits as in van den Heuvel (2008) (see also Diamond and Rajan (2000) and Gorton and Winton (2000)).

an excessively high level of capital for the high-value bank. The second one is sensitive capital requirements that require costly inspection and penalty. If the inspection is not too costly, the regulator chooses sensitive capital requirements. The capital requirement for the high-value bank increases with the inspection's noise. Such an increase counteracts the stronger incentive for a low-value bank to misreport because stronger noise makes it less likely that the regulator detects and punishes the misreporting bank. Such an arrangement is similar to complementing the Basel II risk-based capital requirements with an upper bound on leverage that is independent of bank's risk (the so called Basel III leverage ratio) (see also Blum (2008)). If the inspection is sufficiently noisy or costly, the regulator imposes the insensitive capital requirement.

We then analyze the case with a secondary market where the bank can sell the project to competitive outside investors and redeploy its capital into new investment. The investors have two features. First, contrary to the bank whose default is more socially costly than investors' default, the investors are unregulated.[7] Second, the investors infer the project's value from the bank's level of capital that reflects information gathered by the regulator.[8] These two features are enough to intertwine bank capital regulation and the secondary market in a non-trivial way: The secondary market has two counteracting welfare effects whose strength depends on the sensitivity of capital requirements to the project's value. The (ex post) social benefit is that the bank capital can be used more efficiently when the bank sells the project to the unregulated investors and redeploys the capital to new investment. The benefit increases with the bank's capital requirement because a larger amount of capital is redeployed. The social cost under sensitive capital requirements is caused by a stronger incentive of the low-value bank to misreport due to a possibility of selling the project as a high-value bank. The social cost under the insensitive capital requirement is that the project trades at an adverse selection discount that arises because insensitive capital requirements do not allow the investors to infer the project's value from the bank's capital level.

We show that the insensitive capital requirements become more socially desirable when the

[7] This assumption allows us to *endogenize* the social benefit of redeploying bank capital to new investment via the secondary market.

[8] This assumption represents the idea that the supervisory bank exams produce information that is new and relevant for the bank's investors. This idea has been well documented empirically by Berger and Davies (1998), Flannery and Houston (1999), Berger, Davies and Flannery (2000), DeYoung et al. (2001), Gunther and Moore (2003), and Perstiani, Morgan and Savino (2010).

secondary market exists. We achieve this result in two steps. First, we show that social welfare from the insensitive capital requirement increases when there is a secondary market. The reason is that instead of tying up excessive amount of capital in the high-value bank by imposing on it a high insensitive capital requirement, bank capital can be used more efficiently by selling the project and redeploying into new investment opportunities. If adverse selection is not severe, the social benefit from avoiding an excessive capital requirement on the high value bank by redeploying capital to the new investment is higher than the cost of selling the project at the adverse selection discount.

Second, we show that sensitive capital requirements become socially inefficient when the regulator does not constraint the bank's ability to sell the project. The social benefit of selling the project is low under sensitive capital requirements because such capital requirements already reduce the level of capital the high-value bank has to invest in its project. Moreover, the possibility that the investors can infer the true project's value from the sensitive capital requirements turns out to be socially costly. If the low-value bank anticipates that the high-value bank might sell, misreporting is more profitable than if the high-value bank does not sell. The reason is that the low-value bank could sell its project for the price of the high-value project rather than keep it and lower its capital requirement.

The result is that sensitive capital requirements become socially inefficient for one of two reasons depending on the level of benefit from misreporting: (i) the low-value bank always misreports, leading to its undercapitalization and adverse selection on the secondary market, or (ii) the cost of additional inspection and recapitalization to counteract the increased benefit of misreporting is higher than the social benefit of redeploying capital. As a result, the necessary condition for sensitive capital requirements to be socially efficient is to impose sufficiently high capital requirements on the new investment so as to discourage the high-value bank from selling its project. Hence, sensitive capital requirements become less socially desirable relative to insensitive requirements because the social benefit of the secondary market materializes only in case of the insensitive capital requirements.

Our model predicts that regulatory efforts to create transparency with sensitive capital requirements will backfire and result in lack of transparency and undercapitalized banks when there are no restrictions on banks' asset sales. This suggests that any risk-based capital requirements, such as those from Basel II or SEC's net capital rule, may be detrimental for banks' capitalization and transparency. This may occur especially if these capital requirements are combined with measures such as Basel III leverage ratio or standardized haircuts that might induce banks with high quality assets to sell them, and therefore increase the incentive of banks with low quality assets to misreport.

The paper offers some policy implications. First, the necessary condition for transparency under sensitive capital requirements is to discourage banks with high-quality assets to sell them. Second, discouraging banks from selling their assets eliminates, however, the social benefit of secondary markets which is to put existing bank capital to more productive use. Hence, the paper suggests that, in contemporary banking system, where many bank assets are tradeable, a high capital requirement uniform across all banks would be better than capital requirements based bank's reporting that offer banks substantial rewards for "gaming" them. Finally, the sensitivity of capital requirements to information reported by the banks might depend on the tradability of banks' assets: with sensitive capital requirements for assets that are not easily sold (such as loans to small businesses) and high insensitive capital requirements for assets that can be sold easily (such as mortgages).

The novelty of our paper is to endogenize the link between bank capital regulation and secondary markets and relate it to bank's private information. As such, the paper is related to several independent strands of the banking literature: on the role of secondary markets, information revelation, and the role of bank's private information in bank regulation. Gorton and Pennacchi (1995) and Pennacchi (1988) study the effect of secondary markets on banks' ex post incentive to monitor, while Parlour and Plantin (2008) study the effect on the ex ante incentive to monitor. In contrast, we study a different question: the effect of secondary markets on banks' incentive to misreport. We show that the combination of capital requirements that depend on the bank's private information and the secondary market is socially inefficient. Aghion et al (1999), Mitchell (2001), and Bruche and Llobet (2011) study banks' incentive to reveal their non-performing assets during banking crises. Our paper instead focuses on the incentive to misreport by solvent banks and its impact on the bank capital regulation. In that sense, our case without the secondary market is similar to Prescott (2004) and Blum (2008), who derive risk-based capital requirements when risk is a bank's private information. Moreover, our presentation of the moral hazard problem is an extension of Holmstrom and Tirole (1997) to adverse selection (see also Morrison and White (2005)).

The remainder of the paper is organized as follows. Section 1 describes the model. In Section 2 and 3, we derive optimal capital requirements without and with the secondary market for the bank's project. Section 4 discusses the results and policy implications. Section 5 concludes the paper. The Appendix contains proofs of the results and extensions of the model.

1 Model

Consider an economy with three dates, $t = 0, 1, 2$. There are three types of agents: a bank, a regulator, and investors (who are described in Section 4).

1.1 Bank

The bank is owned and managed by risk-neutral shareholders protected by limited liability (from now on, terms "bank" and "shareholders" mean the same). At $t = 0$ the bank can invest in a project of size 1 described below. The bank funds the project with capital k and deposits $1 - k$. Capital is supplied by the shareholders, who can invest in an alternative project yielding a net return $\delta > 0$. Deposits are fully insured by a government-sponsored deposit insurance agency and supplied at an interest rate normalized to 0.[9] Positive δ captures the idea that capital is more expensive for the bank than deposits. As in van den Heuvel (2008), higher cost of capital is justified by depositors' preference for liquidity: depositors accept a return on deposits lower than on the alternative project in exchange for liquidity services provided only by deposits. We do not model depositors' liquidity preference because an explicit derivation of the difference between the cost of capital and deposits is immaterial for the results.[10]

[9] The case of uninsured deposits is discussed in Section 4.2 and the case of outside shareholders in Section 4.3.

[10] Van den Heuvel (2008) derives a positive difference between the cost of capital and deposits in a general equilibrium framework with competitive banks and households with a preference for liquidity.

At $t = 0$ there are two types of projects, $i = H, L$. The probability that the bank faces the project of type H (L) is $\pi \in (0; 1)$ $(1 - \pi)$. π is known to all agents. i becomes private information of the bank before it chooses k. The project i pays a gross return $1 + r_i$ at $t = 2$ with probability 1 if the bank monitors the project at $t = 1$. If the bank does not monitor the project, the project fails and pays nothing at $t = 2$, but the bank receives a private benefit in a monetary equivalent of b and defaults on its claims to depositors. The bank's monitoring decision is unobservable to other agents. Although the return on the monitored project is deterministic, the setup can be extended to risky returns as shown in Appendix B, so that the results of the paper extend to risk-based capital regulation used in reality.

We assume that

$$r_H > r_L > \delta, \tag{1}$$

and

$$1 > b > r_H. \tag{2}$$

(1) means that the project H is more profitable than L and both projects are profitable under 100% capital financing ($k = 1$). (1) allows us to study the incentive of a solvent bank to misreport its i and eliminates algebraically tedious cases in which the bank finds the project unprofitable for sufficiently high k.[11] (2) means that the project i is socially valuable only if the bank monitors it and implies that the unregulated bank i does not monitor. We use the moral hazard problem a la Holmstrom and Tirole (1997) to model the consequences of the bank's undercapitalization due to misreporting because we can endogenize capital regulation in a simple way. Alternatively, we could use the VaR approach used in bank capital regulation in reality, such as the standard credit risk model used to justify the Basel II capital requirements (Repullo and Suarez (2004)). However, such an approach would complicate the algebra without changing the results.

The setup intends to capture the idea that the bank's monitoring decision is influenced by its private information about the value of a project that is already on the bank's balance sheet (e.g., Rajan (1992), von Thadden (2004)). To capture this idea more realistically, we could have assumed

[11] $\delta > r_i$ (at least for $i = L$) would complicate the incentive compatibility constraints described later due to additional cases where the bank does not undertake the project for sufficienlty high k. The additional cases do not provide new insights because the misreporting incentive would still exist.

that the bank learns i after it chooses k. As Appendix B shows, such a change is immaterial for the results because the cost of capital is constant across t so the timing of choice of k does not matter for the bank's subsequent decisions.[12] Moreover, the model is meant to describe events during a particular state of the economy known to all agents. Hence, realization of i is attributed to the idiosyncratic features of the project observed only by the bank and does not provide any additional signal about the state of the economy.

1.2 Regulator

The bank i, i.e., the bank with project i, that is unregulated does not monitor the project and defaults. To see this observe that when the unregulated bank chooses $k \geq 0$ at $t = 0$, its return on the project i is:

$$\max\left[b; 1 + r_i - (1 - k)\right] - k\left(1 + \delta\right). \tag{3}$$

The first term in (3) is the bank's payoff from the project. Max-indicator reflects the bank's monitoring decision at $t = 1$. If the bank does not monitor, its payoff is b due to limited liability. If the bank monitors, its payoff equals what remains from the project's return after repaying depositors, $1 + r_i - (1 - k)$. $k(1 + \delta)$ is the opportunity cost of capital invested in the bank. The unregulated bank i chooses $k = 0$ because $\delta > 0$ implies that (3) is decreasing in k. Given that (2) leads to $b > r_i$, the unregulated bank prefers not to monitor and defaults on its claims to insured depositors that have to be repaid by deposit insurance.

We assume that the unregulated bank's default leads also to additional social costs $C > 0$ such as caused by disruptions in payment systems, loss of valuable lending relationships or contagion effects. C and insured depositors' indifference toward the bank's monitoring decision provide a need for bank regulation. The additional purpose for assuming that $C > 0$ is to endogenize the social benefit of the project's sale to investors whose default is not as socially costly as bank's default (see e.g. Duffie (2007)).[13] The power to regulate the bank belongs to a regulator who

[12] Once the cost of capital varies with t and the bank is subject to capital regulation, the timing of choice of k would influence the bank's return on misreporting. However, because we want to concentrate on misreporting incentive constant $\delta > 0$ is sufficient. Hence, we can assume that the bank learns i before it chooses k.

[13] Moreover, section 4.2 shows that there is still scope for regulation if $C > 0$ and deposits are *un*insured.

maximizes social welfare. Although the regulator cannot observe whether the bank monitors the project, the regulator can observe and regulate the bank's capital k.[14] We refer to the level of capital required by the regulator as capital requirements.

The bank i monitors when its payoff from monitoring is not lower than b:

$$1 + r_i - (1 - k) = r_i + k \geq b.$$

Monitoring is more attractive when the project's net return r_i and the level of capital k increase. Solving the above inequality for k yields that the minimum level of capital providing the bank i with an incentive to monitor is $\underline{k_i} = b - r_i$. Moreover, it holds that $\underline{k_H} < \underline{k_L}$. The minimum level of capital needed to provide incentive for monitoring is higher for the bank L than for the bank H because the project L yields a lower return for which private benefits are more desirable.

If i were observable at no cost, the regulator would require the bank i to hold the minimum level of capital that provides incentive to monitor, $\underline{k_i}$. First, lower level of capital than $\underline{k_i}$ would result in the bank's social cost of default. Second, more capital than $\underline{k_i}$ is socially costly because capital is more expensive than deposits. To see this observe that, if the bank i monitors, social welfare equals the bank i's return on the monitored project, $1 + r_i - (1 - k) - k(1 + \delta) = r_i - k\delta$. Positive δ implies that the capital requirements are socially costly because the bank cannot fully use its ability as liquidity provider and finance the project with deposits in full.[15]

Once i is the bank's private information, introducing capital requirements equal to $\underline{k_H}$ and $\underline{k_L}$ results in default of the bank L. The bank L saves on capital by choosing $\underline{k_H}$ and does not monitor the project because $\underline{k_H} < \underline{k_L}$. As a result, the bank L defaults, leading to socially costly default.[16]

[14]In this simplified setup, the supervisor would observe at $t = 2$ whether the bank monitored the project. However, we assume that the supevisor does not have tools that could be used at $t = 2$ to provide the bank with an incentive to monitor. Alternatively, we could have assumed that the project fails with some small probability if the bank monitors.

[15]Positive δ is a reduced form of the social cost of capital requirements proposed in Van den Heuvel (2008) where they are socially costly because they reduce the amount of deposits and therefore the provision of liquidity. Their social cost increases with the strength of depositors' liquidity preference reflected in the difference in the cost of equity and deposits as proxied here by δ. See also Diamond and Rajan (2000) and Gorton and Winton (2000).

[16]Using (3), $\underline{k_i} = b - r_i$ and $r_H > r_L$, we can show that the bank L's return from choosing $\underline{k_H}$ and not monitoring, $b - (1 + \delta)\underline{k_H}$, is higher than from choosing $\underline{k_L}$, $r_L - \delta\underline{k_L}$: $b - (1 + \delta)\underline{k_H} = r_H - \delta\underline{k_H} > r_L - \delta\underline{k_L} = b - (1 + \delta)\underline{k_L}$.

To simplify the exposition of the results, we assume that

$$\pi < \pi_C = \frac{(1+\delta)\left(1-\underline{k_L}\right)+C}{(1+\delta)\left(1-\underline{k_L}\right)+\delta(r_H-r_L)+C}. \tag{4}$$

(4) means that the regulator prefers to impose an insensitive capital requirement $\underline{k_L}$ on each bank i if i is unknown to the regulator, i.e., the regulator prefers that each bank i always monitors its project. Such a capital requirement $\underline{k_L}$ imposes a burden on the bank H that has to hold more capital than $\underline{k_H}$, but it eliminates social cost of default of bank L.[17] (4) reduces the regulator's problem to a choice between the insensitive capital requirement $\underline{k_L}$ for each bank i and capital requirements that are sensitive to i and backed by a supervisory scheme described next.

To implement sensitive capital requirements, the regulator can gain insight about i using a supervisory scheme. The scheme consists of two instruments: inspection taking place upon the bank's report of i and a penalty. Inspection has a cost m, is stochastic, and is noisy. The regulator inspects with probability q when the bank reports H and there is no inspection when the bank reports L.[18] The regulator detects the true i with probability $\gamma \in (1/2;1)$. With probability $1-\gamma$, the regulator detects a type different from the true i.[19] If the detected type is different from the bank's report, the regulator can impose a penalty on the bank. The regulator can use two penalties: recapitalization and the project's sale if there is a secondary market for the bank's project.[20]

[17] Social welfare under $\underline{k_L}$ for each bank i is the bank's expected return on the monitored project: $\pi(r_H-\delta\underline{k_L})+(1-\pi)(r_L-\delta\underline{k_L})$. Social welfare when the bank L chooses $\underline{k_H}$ is the bank's expected return if it monitors the project H and defualts on the project L: $\pi(r_H-\delta\underline{k_H}-(1+\delta)(1-\pi)\left(1-\underline{k_H}\right))+(1-\pi)(b-(1+\delta)\left[\underline{k_H}+(1-\pi)\left(1-\underline{k_H}\right)\right]-C)$, where the regulator imposes a fair deposit insurance premium $(1-\pi)\left(1-\underline{k_H}\right)$ on each bank i. The premium appears only as the bank's opportunity cost because the deposit insurance payout and revenue from the premium are equal in expected terms. Comparing both expressions for social welfare delivers (4).

[18] It can be shown formally that when both types of the bank report i truthfully, it is not optimal to inspect the type that has the incentive to misreport, i.e., type L. See Khalil (1997) for a similar treatment.

[19] In a general case, the probability of mistake would differ across i.

[20] We use the two most common tools to deal with undercapitalized banks and assume away penalties such as fines and bank closures. First, a bank supervisor would not use fines that are disputable in court when speed of recapitalization matters. Second, a closure of a solvent bank may be too costly for the regulators.

2 Capital requirements without the secondary market

In this section we derive capital requirements and supervisory scheme when there is no secondary market for the bank's project, i.e., there are no outside investors to buy the project. Hence, the regulator can use only recapitalization as penalty.

The timing is as follows. At $t = 0$ the regulator chooses and commits to the capital requirements k_H and k_L, the probability of inspection q upon report of H, and a penalty with recapitalization: an increase in the level of capital by x.[21] Next, the bank learns i and decides which type to report to the regulator. The regulator conducts inspection with probability q if the report is H and punishes the bank if the detected type is L. The regulator does nothing if the report is L. If the bank reports H and is not punished, it finances the project with capital level k_H. If the bank reports H and is punished, it finances the project with capital level $k_H + x$. If the bank reports L, it finances the project with capital level k_L. At $t = 1$ the bank decides whether to monitor the project. At $t = 2$ the returns are realized. The timing of the events is summarized in Figure 1.[22]

Formally, the regulator solves the following problem:

$$\max_{k_H, k_L, q, x} \pi(r_H - \delta k_H - q(1-\gamma)\delta x) + (1-\pi)(r_L - \delta k_L) - \pi q m. \tag{5}$$

subject to

$$k_H \geq \underline{k_H}, k_L \geq \underline{k_L}, \tag{6}$$

$$r_L - \delta k_L \geq (1 - q\gamma)\left[\max\left[b; r_L + k_H\right] - k_H(1+\delta)\right] + q\gamma\left[\max\left[b; r_L + (k_H + x)\right] - (1+\delta)\left(k_H + x\right)\right], \tag{7}$$

$$r_H - \delta k_H - q(1-\gamma)\delta x \geq r_H - \delta k_L, \tag{8}$$

$$x \leq 1 - k_H, \tag{9}$$

$$q \in [0; 1]. \tag{10}$$

[21] The case when the regulator cannot commit to the supervisory scheme is discussed in Section 4.4.

[22] Because the project is financed after the report labeling the penalty as "recapitalization" is a slight terminology abuse. We use the term "recapitalization" because a change in timing of events allowing for proper use of this term is immaterial for results as shown in Appendix B.

The regulator chooses k_H, k_L, q, and x to maximize social welfare (5) subject to constraints (6)-(10). Social welfare (5) is the bank's expected return (the first two terms) net of the expected inspection cost (the last term). The bank's expected return takes into account that the regulator wants each bank i to reveal its i truthfully and to monitor due to (4). The first term in (5) is the bank H's return equal to the return on the monitored project, $r_H - \delta k_H$, net of expected cost of recapitalization, $q(1-\gamma)\delta x$. With probability $q(1-\gamma)$ the regulator inspects the bank H and erroneously detects L, which leads to recapitalization due to the commitment to the supervisory scheme. Recapitalization leads to a cost δx because it lowers deposits by x but it has an opportunity cost of $(1+\delta)x$. The second term in (5) is the bank L's return on the monitored project. The last term, the expected inspection cost, is $\pi q m$ because under truthful reporting, the regulator inspects with probability q when the bank is H, which occurs with probability π.

(6) ensures that each bank i has enough capital to monitor its project after revealing its type truthfully. (7) guarantees that the bank L reports its type truthfully. $r_L - \delta k_L$ is the bank L's return under truthful reporting. The right-hand side of (7) is the bank L's expected return if it reports H. With probability $(1-q) + q(1-\gamma) = 1 - q\gamma$ the bank L is either not inspected or inspected but not caught on misreporting, so it finances with capital k_H. With probability $q\gamma$ the bank L is caught on misreporting and is required to finance with capital $k_H + x$. The bank L's decision whether to monitor depends on its capital level as expressed by the max-operator. (8) guarantees that the bank H reports its type truthfully. The left-hand side of (8) is the bank H's return if it reports H and the right-hand side is the return if it reports L. If the bank H reports L, it monitors the project because $k_L \geq \underline{k_L} > \underline{k_H}$. (9) is the upper bound on x because recapitalization can lead maximally to 100% capital financing. (10) is the usual constraint on probability. The bank's participation constraints are ignored because they are implied by (1), (7), and (8).

The solution to the regulator's problem delivers the following proposition.[23]

Proposition 1 *Suppose there is no secondary market for the bank's project. For each $\gamma \in (1/2; 1)$ and $\delta \in (0; r_L)$ there exist a function $m(\gamma)$ as well as q and x satisfying (7)-(10) such that*

[23] Whenever social welfare for the insensitive and sensitive capital requirements is the same, we assume the regulator chooses sensitive capital requirements.

social welfare is maximized if $k_L = \underline{k_L}$ *and:*

1. $k_H = \underline{k_L}$ *for any* $m > m(\gamma)$;

2. $k_H = \underline{k_L} - \frac{\gamma\delta(1-\underline{k_L})}{(1-\gamma)(1+\delta)} \in \left(\underline{k_H}; \underline{k_L}\right)$ *for* $m \in (0; m(\gamma)]$, $\gamma \in [\gamma_1; \gamma_2)$ *and* $\underline{k_L} > \underline{k_H} + (1-\gamma_1)\left(1-\underline{k_H}\right)$, *where* $\gamma_1 = 1 + \delta - \sqrt{\delta(1+\delta)}$ *and* $\gamma_2 = \frac{(1+\delta)(r_H - r_L)}{r_H - r_L + \delta(1-\underline{k_H})}$;

3. $k_H = \underline{k_H}$ *for* $m \in (0; m(\gamma)]$ *and* $\gamma \in [\max[\gamma_1; \gamma_2]; 1)$.

$m(\gamma)$ *is* 0 *for* $\gamma \leq \gamma_1$ *as well as positive and increasing in* γ *for* $\gamma \in (\gamma_1; 1)$.

Proof. See Appendix A. ■

The proposition is illustrated in Figure 2. The regulator faces the following tradeoff. An insensitive capital requirement that guarantees the bank L's monitoring would impose an excessive capital on the bank H. Sensitive capital requirements would reduce the bank H's capital level but require costly supervisory scheme to ensure that the bank L does not misreport. As a result, the regulator chooses the sensitive capital requirements for sufficiently low inspection cost m and sufficiently high probability of detecting true type γ (the cases 2 and 3). If γ is sufficiently low ($\gamma \leq \gamma_1$), the probability of detecting bank L's misreporting is so low that the resources spent by the regulator to detect true i make the sensitive capital requirements too costly in welfare terms for any positive m.

For intermediate γ and sufficiently high $\underline{k_L}$ (the case 2) the regulator can introduce only such sensitive capital requirements that optimal k_H is higher than $\underline{k_H}$.[24] The reason is that the probability of detecting bank L's misreporting is so low that the bank L would always misreport its type for $k_H = \underline{k_H}$, even when the regulator always inspects ($q = 1$) and after recapitalization the bank has to finance the project with 100% equity ($k_H + x = 1$). Hence, the only way to eliminate the bank L's incentive to misreport is to reduce its return from misreporting by introducing k_H bigger than $\underline{k_H}$.

[24] See Blum (2008) for a similar result.

3 Capital requirements with the secondary market

3.1 Investors

In this section we assume that after having financed the project, the bank can sell it on a secondary market. Given the general nature of the model, the project's sale can be interpreted as a sale either of loans or of collateralized loan obligations. After selling the project and repaying the depositors the bank can pay out the rest of the proceeds from the sale to the bank's shareholders, who can invest proceeds in the alternative project yielding a net return δ.[25] We assume that the bank has to repay deposits before it pays out any of the proceeds from the sale.

There is a large number of risk-neutral and competitive investors who can buy the project from the bank but cannot originate it. The investors can finance the purchase with their capital with the same opportunity cost as the bank's shareholders' capital, $1 + \delta$, and uninsured deposits that are supplied on a competitive market at an interest rate normalized to 0. The investors earn the return $1 + r_i$ when they monitor the project, and earn b if they do not. There are two crucial differences between the bank and the investors.[26] First, there is no social cost of investors' default.[27] Second, the investors do not have technology to obtain information about i on their own before they purchase the project.[28] However, they can infer it from the bank's capital before they purchase the project, or they learn it after the purchase.

Assuming the same financing and project's return structure for the bank and the investors may seem very strong. Especially, some buyers of banks' assets in reality, such as hedge funds, distressed debt funds, finance companies, do not provide liquidity such as banks do that would justify the same cost of capital (Duffie (2007), Drucker and Puri (2009)).[29] However, we make

[25] The implicit assumption of no investment opportunities within the bank at the time of the project's sale simplifies the analysis without affecting the results. In fact, the alternative project could be used to proxy for such opportunities (see Parlour and Plantin (2008)).

[26] Section 4.2 shows that the assumption that the bank uses insured deposits is used only for algebraic convenience.

[27] Although there is no reason to regulate the investors, there might be still scope for the regulator to inspect them given $\delta > 0$. We assume it away because we want to study the effect of the secondary market on the misreporting incentive in the simplest possible model.

[28] Relaxing this assumption would lead to two issues beyond the scope of this paper: who is more efficient in learning i, and what are the incentives to free-ride on provision of information about i.

[29] We deliberately exclude other commercial and investment banks from the set of potential investors, because recent literature has pointed out that their engagement on secondary markets might have been due to regulatory arbitrage inherent in existing capital regulation (Acharya et al. (2010), Nadauld and Sherlund (2008)). Such a

these assumptions in order to show that a non-trivial relationship between bank capital regulation and the secondary market in our model is driven rather by more fundamental differences between banks and potential buyers of their assets: banks' importance and their informational advantage. Appendix C shows that allowing for further differences between the bank and the investors does not affect the model's main insight, which is the link between bank capital regulation and the secondary market.

3.2 Optimal capital requirements

We assume that the regulator is also able to set capital requirements for the bank that sells its project and use the project's sale as a penalty. The project's sale by the punished bank is described with a variable s that takes value of 1, when the punished bank has to sell, and 0 otherwise.

The timing from Section 2 is modified as follows. At $t = 0$ the regulator chooses and commits to the capital requirements k_H and k_L, the capital requirements k_H^S and k_L^S for the bank that sells the project, the probability of inspection q upon report of H, and penalties x and s. Next, the bank learns i and decides which type to report to the regulator. The regulator conducts inspection with probability q if the report is H and punishes the bank if the detected type is L. The regulator does nothing if the report is L. If the bank reports H and is not punished, it finances the project with capital level k_H. If the bank reports H and is punished, it finances the project with capital level $k_H + x$. If the bank reports L, it finances the project with capital level k_L. At $t = \frac{1}{2}$ the investors offer a price for the project, the amount of capital they pledge to invest, and the deposit rate they pay for the uninsured deposits. The bank that is not punished chooses whether to accept or reject an investor's offer. If the bank sells the project and reported H (L), it adjusts its capital according to k_H^S (k_L^S), pays out the proceeds from selling after repaying the depositors, and its shareholders invest in the alternative project. The punished bank sells only if $s = 1$.[30] At $t = 1$ the owner of the project decides whether to monitor. At $t = 2$ the returns are realized. The timing

regulatory arbitrage is not the topic of this paper.

[30] Without loss of generality, the punished bank H that sells is subject to the same capital requirement k_H^S as the bank that is not punished. We show in the proof of Lemma 4 the regulator will eliminate the incentive to sell for any bank.

of the events is summarized in Figure 3.[31]

In order to determine the optimal capital requirements, we proceed as follows. First, we derive optimal capital requirements separately for two cases: when the regulator does not inspect the bank ($q = 0$) and inspects it ($q > 0$). The reason is that each case has different implications for outcomes on the secondary market as explained below. Second, we determine the optimal capital requirements by comparing social welfare from the optimal capital requirements for $q = 0$ and $q > 0$.

3.2.1 The case without inspection

We now analyze the optimal choice of capital requirements when the regulator does not inspect. Because social welfare depends on the bank's return, we first analyze equilibria on the secondary market at $t = \frac{1}{2}$ after the bank has chosen its capital requirements at $t = 0$. We present the solution for insensitive capital requirements, $k = k_H = k_L$ and $k^S = k^S_H = k^S_L$, because, as we show in the proof of Lemma 3, the regulator can achieve the highest social welfare for $q = 0$ using insensitive capital requirements. Sensitive capital requirements without inspection cannot deliver higher welfare than the insensitive because the bank L always has an incentive to misreport, not allowing the regulator to lower the capital requirement for the bank H below $\underline{k_L}$.

At $t = \frac{1}{2}$ the investors offer only one price P because they cannot infer the bank's i from the bank's choice of capital requirements if they are insensitive.[32] While choosing a price P, the investors anticipate the bank i's incentive to sell the project. If the bank i does not sell, its payoff depends on whether k is high enough to provide the bank with an incentive to monitor:

$$\max\left[b; 1 + r_i - (1 - k)\right] = \max\left[b; r_i + k\right].$$

[31] We assume away the possibility that the bank can sell between learning and reporting i. If $q = 0$, this does not matter. If $q > 0$, selling before i is revealed to the investors is not optimal because it would lead to selling at most for a pooling price.

[32] We assume that the investors do not observe the bank's report to the regulator because it simplifies the description of the equilibria without changes in results. Moreover, signalling with capital is not possible because its cost is the same for each bank i. Even if signalling with capital were possible, it would not be socially efficient, because capital invested by the bank H would never be lower than $\underline{k_L}$. Otherwise, the bank L would always mimick the bank H and default.

The opportunity cost of investing capital in the project does not enter the bank's payoff at $t = \frac{1}{2}$ because it is sunk at $t = 0$. If the bank i sells, the project its payoff is

$$\left(k^S - k\right) - (1 - k) + \left[P - \left(k^S - k\right)\right](1 + \delta) = (P + k)(1 + \delta) - 1 - k^S\delta,$$

where $\left(k^S - k\right)$ is the additional amount of capital invested in the bank according to k^S, $(1 - k)$ is the payout to the depositors, and $P - \left(k^S - k\right)$ is the available capital that the bank redeploys into the alternative project to earn $1 + \delta$ per unit invested. Because the bank has to repay deposits $1 - k$ after selling the project, $k^S - k$ has to be high enough to cover $1 - k$, i.e., $k^S \geq 1$. Comparing the last two expressions for the bank i's payoffs delivers that the bank i sells if P is high enough

$$P \geq P_i^R \equiv \frac{1 + k^S\delta + \max\left[b; r_i + k\right]}{1 + \delta} - k.$$

P_i^R is the reservation price of the bank i. P_i^R decreases in k, meaning that the bank is more willing to sell if k increases. The reason is that by selling the bank can free up and redeploy more capital to the alternative project where it earns $1 + \delta$ on each unit of capital. P_i^R also increases in k^S. Moreover, it holds that $P_H^R \geq P_L^R$ for any k and k^S, meaning that the bank H is less willing to sell than the bank L.[33] The reason is that the project H is more valuable than L. Hence, one of three possible outcomes on the secondary market can arise for given P as well as k and k^S that determine the reservation prices: (i) each bank i sells if $P \geq P_H^R$, (ii) only the bank L sells if $P \in \left[P_L^R; P_H^R\right)$ and $P_H^R > P_L^R$, or (iii) none of the banks sells if $P < P_L^R$.

The competitive investors offer the highest possible P anticipating the bank's reservation prices given k and k^S. The investors finance the purchase of the project for a price P with their own capital e and uninsured deposits $P - e$. The investors can attract cheap, uninsured deposits only if they commit to monitoring the project. Hence, P and e are determined not only by the investors' participation constraint but also by their incentive compatibility constraint, ensuring that the investors monitor the project by investing their own capital. How much capital the investors invest depends on their own and depositors' anticipation of which project will be sold (i.e., which

[33] To see this observe that $P_H^R - P_L^R = \frac{\max[b; r_H + k] - \max[b; r_L + k]}{1+\delta} \geq 0$ because $r_H > r_L$.

bank will sell).

First, if only the bank L is anticipated to sell, the investors invest capital sufficient to monitor the project L. Because the project L succeeds with probability 1, the investors offer also net deposit rate 0 for deposits. Hence, the investors' incentive compatibility constraint reads that their return on the monitored project L after repaying deposits, $1 + r_L - (P - e)$, cannot be lower than b. The investors' participation constraint reads that the investors' return covers the opportunity cost of investing capital in the project, $e\,(1+\delta)$. Both constraints boil down to

$$1 + r_L - (P - e) \geq \max\left[b; e\,(1+\delta)\right].$$

Second, if each bank i is anticipated to sell, the investors can attract deposits by committing to one of two monitoring decisions. On the one hand, the investors may commit to monitor both projects. They pay a deposit rate 0 because the projects always succeed. The incentive compatibility constraint is the same as if only the bank L sells because i is unknown at the time of purchase. Hence, the investors have to invest so much capital up-front that they commit to monitor the less valuable project L. The participation constraint reads that the expected return on both projects after repaying deposits covers the opportunity cost:

$$\pi\,(1 + r_H) + (1 - \pi)\,(1 + r_L) - (P - e) \geq e\,(1 + \delta)\,.$$

On the other hand, the investors may commit to monitor only the project H and default on the project L. At the time of purchase, the expected probability of investors' default is the probability that the project is L, $1 - \pi$. The investors are still able to attract the uninsured deposits by compensating them with a deposit rate $\frac{1}{\pi} - 1 > 0$.[34] Hence, the incentive compatibility constraint reads that the investors' return on the project H after repaying the deposits, $\frac{1}{\pi}\,(P - e)$, is not lower than b:

$$1 + r_H - \frac{1}{\pi}\,(P - e) \geq b.$$

[34] The depositors expect to be repaid with probability π. If the gross deposit rate is $1 + d$, the depositors break even on every unit lent to the investors if $\pi\,(1 + d) = 1$, so the net deposit rate is $d = \frac{1}{\pi} - 1$.

The investors' participation constraint guarantees that the investors' expected return on the project covers the opportunity cost:

$$\pi\left(1+r_H-\frac{1}{\pi}(P-e)\right)+(1-\pi)b\geq e(1+\delta),$$

which takes into account that the investors earn b and default if the project is L. The investors choose e and the highest possible P, taking into account their own constraints and anticipating the bank's selling decision.

The following proposition characterizes the outcomes on the secondary market under k, k^S and $q=0$.

Lemma 2 *Suppose there is a secondary market for the bank's project and* $q=0$, $k=k_H=k_L$, $k^S=k_H^S=k_L^S$. *Denote* $k_{P1}=\underline{k_L}+\frac{(1-\pi)(r_H-r_L)}{\delta}$, $k_{P2}=\underline{k_H}+\frac{(1-\pi)(1+\delta)\left(1-\underline{k_H}\right)}{\delta}$ *and* $\pi_0=\frac{(1+\delta)\left(1-\underline{k_L}\right)}{(1+\delta)\left(1-\underline{k_L}\right)+\delta(r_H-r_L)}<\pi_C$. *One of four cases may arise depending on* k, k^S and π.

1. *For* $k\geq k_{P1}+k^S-1$, $k^S\leq 2-k_{P1}$, *and* $\pi\in(0;\pi_0)$ *each bank* i *sells the project for a price* $\pi(1+r_H)+(1-\pi)(1+r_L)-\delta\frac{b+\pi(r_H-r_L)}{1+\delta}$. *The investors invest capital* $\frac{b+\pi(r_H-r_L)}{1+\delta}$ *and monitor each project* i.

2. *For* $k\geq k_{P2}+k^S-1$, $k^S\leq 2-k_{P2}$, *and* $\pi\in[\pi_0;\pi_C)$ *each bank* i *sells the project for a price* $\pi(1+r_H)+(1-\pi)b-\frac{\delta b}{1+\delta}$. *The investors invest capital* $\frac{b}{1+\delta}$ *and monitor only the project* H.

3. *For* $k\in\left[\underline{k_L}+k^S-1;\min\{k_{P1};k_{P2}\}+k^S-1\right)$, $k^S\leq 2-\underline{k_L}$, *and* $\pi\in(0;\min\{1-\frac{\delta(r_H-r_L)}{(1+\delta)\left(1-\underline{k_H}\right)};\pi_C\})$ *only the bank* L *sells the project for price* $1+r_L-\frac{\delta b}{1+\delta}$. *The investors invest capital* $\frac{b}{1+\delta}$ *and monitor the project.*

4. *For any other* k, k^S, and π, *none of the banks sells the project.*

Proof. See Appendix A. ■

Lemma 2 highlights the role of capital requirement k for the bank's incentive to sell its project. If k is sufficiently high, even the bank H sells the project, because the return on capital k from the alternative project is so high that it compensates for selling the project at a discount to its true value (the cases 1 and 2). As it can be seen from the prices paid by the investors, the discount has two sources: adverse selection (the first two terms in expression for the project's price) and investors' financing of the purchase with costly capital (the third terms in expression for the project's price) . If k falls below the thresholds from the case 1 or 2 only the bank L sells its project (the case 3). For some low k even the bank L keeps the project (the case 4). Lemma 2 shows also that k^S cannot be too high. Otherwise, the bank would keep the project for any $k \leq 1$.[35]

Lemma 2 also shows that for sufficiently high π (the case 2) the investors offer the highest price when they monitor only the project H despite the fact that by defaulting on the project L yields b instead of $1 + r_L$. The reason is that for sufficiently high π the probability that the project turns out to be L is so low that the savings on lower capital outlay because of monitoring only the project H are higher than the loss of return on the project L.[36]

The consequence of the fact that investors monitor only the project H for sufficiently high π is a difference between the investors' optimal monitoring decision and the bank's socially optimal monitoring decision, which is to monitor both projects for any $\pi < \pi_C$. This difference in the monitoring decisions is the driver of Lemma 3 that presents the optimal capital requirements for $q = 0$. Social welfare is equal to the bank's expected return from each of three possible outcomes on the secondary market because competitive investors' surplus is 0 and the regulator does not inspect.

Lemma 3 *Suppose there is a secondary market for the bank's project and $q = 0$. The highest social welfare can be achieved using insensitive capital requirements $k = k_H = k_L$ and $k^S = k^S_H = k^S_L$ such that the following conditions are fulfilled. k^S is 1.*

1. *For $\pi \in \left[\max\left\{\pi_0; \frac{1}{1+\delta}\right\}; \pi_C\right)$ and $\underline{k_L} \in \left(\underline{k_H}; \min\left\{1; \frac{1+\delta+\underline{k_H}+C}{2+\delta}\right\}\right)$ the optimal k is any*

[35] Separating on the secondary market cannot arise because the investors do not have tools other than price to separate the bank H and L. However, it can be shown that even if the project is divisible, a pooling equilibria from Lemma 2 still exist for sufficiently high π. For such π the bank H prefers to sell the whole project for a pooling price than retain some of it and sell it for a price reflecting the true value of its project.

[36] To see this observe that the difference between the price the investors pay when they monitor only the project H and when they monitor both projects is given by the difference in prices from the case 2 and 1 in Lemma 2. After some algebra this difference equals $\frac{\delta\pi(r_H - r_L)}{1+\delta} - (1-\pi)(1 + r_L - b)$, where the first term is the savings on investors' capital financing and the second is the loss of return from defaulting on the project L. This difference becomes positive for $\pi > \pi_0$.

$k \geq k_{P2}$. *Both banks sell the project and the investors default on the project L. Social welfare is higher than in the case of the insensitive capital requirement* $\underline{k_L}$ *without the secondary market.*

2. *Otherwise optimal* $k = \underline{k_L}$. *The investors never default on the purchased project. Social welfare is the same as in the case of the insensitive capital requirement* $\underline{k_L}$ *without the secondary market.*

Proof. See Appendix A. ■

Lemma 3 is illustrated in Figure 4. If π is sufficiently high (the case 1) the regulator chooses any k for which each bank i sells the project. Any k not lower than k_{P2} is sufficient because the cost of capital is constant over t. Hence, precise choice of k at $t = 0$ does not matter because the bank can recuperate k at $t = \frac{1}{2}$. The regulator prefers each bank to sell the project rather than keep it because the project's sale yields higher expected return on the bank capital than the alternative, which is to make the bank keep the project.[37] The driver of this result is that the investors' optimal monitoring decision is to monitor only the project H. The regulator accepts the investors's default on the project L because their default has no social cost. In contrast, if each bank i were to keep the project, the regulator would require each bank i to invest $\underline{k_L}$ to monitor and prevent their default. Hence, instead of tying so much capital in each bank i, the project can be sold to the investors. The difference in monitoring between the bank and the investors translates into high price for the project through the savings on the investors' financing with costly capital. This high price leads to a higher expected return on bank capital from redeploying it into the new investment. In other words, by selling the project the existing bank capital is put into more productive use and the project sale allows to avoid social cost of excessive capital requirement $\underline{k_L}$ on the bank H.

It is important to note the special role of capital requirements in Lemma 3. In order to realize the social benefit of project's sale the capital requirement k has to be sufficiently high to make

[37] The other possibillity is to make the bank L sell its project and make the bank H keep it. But for this to be profitable for the bank L the capital requirement for the bank H has to be $\underline{k_L}$, which is the same capital requirement if each bank i keeps the project. For any bank H's capital requirement lower than $\underline{k_L}$ the bank L would prefer to keep its project and default.

the bank H to sell its project at an adverse selection discount. Otherwise, the bank H does not internalize this social benefit and will keep its project.

If π is sufficiently low (the case 2), the regulator is indifferent between making the bank keep or sell the project. The reason is that the investors find it optimal to monitor the project for any i which is the same monitoring decision required by the regulator from the bank. Hence, the expected return on bank capital from selling the project is the same as from keeping it, because there are no savings on investors' costly capital financing to be translated into an additional return on the new investment.[38]

The consequence of Lemma 3 is that for sufficiently high π the insensitive capital requirements become more socially desirable when there is a secondary market than when it does not exist. The reason is that the secondary market reduces the bank H's burden from the insensitive capital requirement $\underline{k_L}$ in case the bank were to keep the project.

3.2.2 The case with inspection

Now we analyze the optimal capital requirements when $q > 0$. For $q > 0$ the regulator introduces sensitive capital requirements because inspection would be socially wasteful under insensitive capital requirements. Before we present the regulator's choice of capital requirements, we first discuss the outcomes on the secondary market at $t = \frac{1}{2}$ and then the bank's misreporting incentive at $t = 0$.

We start with the secondary market at $t = \frac{1}{2}$. After the bank reveals its i truthfully to the regulator at $t = 0$, the investors can correctly infer i from the bank's choice of capital requirements k_i. If the punished bank recapitalizes with x, the investors also correctly infer that in a truthtelling equilibrium it can only be the bank H. Hence, the price offered for the project i, P_i, and the capital invested by the investors, e_i, have to be such that the investors' return on the monitored project after repaying deposits, $1 + r_i - (P_i - e_i)$, cannot be lower than the private benefits and the opportunity cost of capital:

$$1 + r_i - (P_i - e_i) \geq \max\left[b; (1 + \delta) e_i\right].$$

[38] Section 4.1 discusses this result when the monitored project's returns are stochastic.

The investors offer the deposit rate of 0 because the monitored project always succeeds. The competitive investors offer $P_i^* = 1 + r_i - \frac{\delta b}{1+\delta}$ and invest capital $e_i = \frac{b}{1+\delta}$ such that the last inequality is binding. The reason is that the investors earn zero profits and invest such amount of capital that guarantees the highest possible price. Proof of Lemma 2 offers the formal argument. The project trades at a discount $\frac{\delta b}{1+\delta}$ to its value due to investors' financing with costly capital.

If the bank i that is not punished at $t = 0$ sells its payoff is analog to the one from the previous section with the only difference that this time we add index i to indicate dependence of capital requirements and the price on the bank's type:

$$\left(k_i^S - k_i\right) - (1 - k_i) + \left[P_i^* - \left(k_i^S - k_i\right)\right](1 + \delta).$$

If the bank i does not sell at $t = \frac{1}{2}$, its payoff is $1 + r_i - (1 - k) = r_i + k_i$, because the regulator imposes $k_i \geq \underline{k_i}$. For any $k < \underline{k_i}$ the bank i keeps the project and defaults.[39] By comparing the bank i's payoffs from keeping and selling as well as using the expression for P_i^*, we get that the bank i sells if the capital requirement for keeping the project is sufficiently high, $k_i \geq \underline{k_i} + k_i^S - 1$. Similarly, the punished bank H is even more willing to sell in order to eliminate the burden from costly recapitalization and sells for $k_i \geq \underline{k_i} + k_i^S - 1 - x$. The last expression arises after comparing the punished bank H's payoff from selling,

$$\left(k_H^S - (k_H + x)\right) - (1 - (k_H + x)) + \left[P_H^* - \left(k_H^S - (k_H + x)\right)\right](1 + \delta),$$

and its payoff from keeping, $1+r_i-(1-k-x) = r_i+k_i+x$, after taking into account recapitalization. Hence, as in the previous section, the bank sells if capital requirements for keeping the project are sufficiently high.

Now we analyze the bank's incentive to report its type truthfully at $t = 0$. First, if k_i, x, and k_i^S are such that each bank i keeps the project at $t = \frac{1}{2}$, the constraints guaranteeing truthtelling are the same as in the case without the secondary market, (7) and (8). Second, once k_i, x, and k_i^S

[39] This can be seen by comparing the bank i's payoff from selling and from keeping, which is b if $k_i < \underline{k_i}$. b is higher than the payoff from selling for $k_i < \underline{k_i} + \frac{\delta}{1+\delta}\left(k_i^S - 1\right)$. Given that k_i^S cannot be lower than 1 (otherwise the bank could not repay its depositors), the bank i will always keep if $k_i < \underline{k_i}$.

are such that at least the punished bank H sells its project at $t = \frac{1}{2}$, the truthtelling constraint for the bank L becomes tighter than (7).[40] The reason is that the bank L's payoff from misreporting is higher than in the case if the bank H does not sell (the first term on the right-hand side of (7)). By reporting H the bank L can sell its low-value project for the price of the high-value one, whereas if it does not sell it keeps the less valuable project and is subject only to a lower capital requirement k_H. Tighter truthtelling constraint for the bank L makes it costlier for the regulator to obtain truthful revelation of the bank L's type because the regulator has to inspect the bank more often and impose harsher penalty.

In fact, if there are no restrictions on the project's sales ($k_i^S = 1$ and $s = 1$), the bank L always misreports and truthtelling unravels for any q and x. Unravelling results in adverse selection on the secondary market, because the investors infer correctly that with some probability the bank L gets away with misreporting and tries to sell its project as the project H. Depending on k_H and severity of adverse selection there are three possible outcomes on the secondary market as in the previous section. In the worst case, none of the banks sells because k_H is so small that even the bank L prefers to keep its project and defaults causing social cost C.

Once the regulator takes into account the negative effect of the secondary market on the bank L's incentive to report its type, the optimal capital requirements k_i^S are as follows.

Lemma 4 *Suppose there is a secondary market for the bank's project and $q > 0$. The regulator finds optimal to discourage the bank H from selling the project by imposing sufficiently high $k_H^S > 1 + k_H - \underline{k_H}$. The optimal k_L^S is equal to or bigger than 1.*

Proof. See Appendix A. ■

Lemma 4 shows that under sensitive capital requirements, the regulator finds it optimal to provide the bank H (whether it is or is not punished) with an incentive to keep the project rather than sell by imposing sufficiently high k_H^S. Sufficiently high k_H^S limits the amount of capital that can be redeployed to the new investment. This limit discourages the project's sale because the amount of capital that can be paid out is so small that the return on it from the alternative

[40] The formal presentation of the bank L's truthtelling constraint is suppressed to the proof of the following lemma.

project cannot compensate for the discount $\frac{\delta b}{1+\delta}$ at which the project trades. By eliminating the bank H's incentive to sell the regulator relaxes the bank L's truthtelling constraint and lowers the social cost of inspection and penalty needed to implement the sensitive capital requirements. It occurs despite of potential benefit from selling. However, the benefit of reducing the burden from capital requirements by selling is low because sensitive capital requirements already reduce the bank H's burden from the costly capital requirements. Hence, the social benefit of the project's sale is outweighed by its cost in terms of the bank L's higher incentive to misreport.[41]

The consequence of Lemma 4 is that the regulator can introduce capital requirements such as $k_H = k_H^{LR}$ from the case 2 in Proposition 1. If there is no secondary market, k_H^{LR} guarantees that the bank L reveals its type for γ such that inspection with $q = 1$ and recapitalization leading to 100% equity financing are not sufficient to do so. However, if there is a secondary market and there is no limit on the amount paid out by the bank beyond what is needed to repay the deposits, the bank H would sell to avoid k_H^{LR} making the truthful revelation of the bank L harder to achieve.[42] Hence, k_H^{LR}, although designed to encourage truthful reporting of i, would backfire by increasing the bank L's incentive to misreport. The only way to return k_H^{LR} to its original purpose of encouraging truthtelling is to discourage selling by the bank H by imposing k_H^S such as in Lemma 4.

After the regulator eliminates the punished bank H's incentive to sell, selling could still be used as a penalty because the project trades at the discount $\frac{\delta b}{1+\delta}$ to its true value. However, selling can be used as a penalty only if such a penalty relaxes the truthtelling constraint of the bank L by sufficiently lowering the bank L's return from being caught on misreporting. This might not always be the case because in the truthtelling equilibrium, only the bank H is punished. Hence, the bank L caught on misreporting would sell as the bank H.

Lemma 5 *Suppose there is a secondary market for the bank's project and $q > 0$. If $\frac{\delta b}{1+\delta} \leq r_H - r_L$ the optimal s is* 0 *and the optimal sensitive capital requirements k_H and k_L are the same as in Proposition 1.*

[41] Section 4.1 discusses Lemma 4 when there is an additional positive welfare effect of the seconadry market if the returns are stochastic.

[42] The bank H sells if $k_H^S \leq 1 + k_H - \underline{k_H}$. Hence, without any restrictions on payouts, $k_H^S = 1$, the bank H sells because $k_H = k_H^{LR} > \underline{k_H}$.

Proof. See Appendix A. ■

If the discount $\frac{\delta b}{1+\delta}$ is too low, the regulator will never use selling as a penalty, $s = 0$, because the bank L's return from being caught on misreporting is so high that the bank L's truthtelling constraint is tighter than (7). $s = 0$ in combination with Lemma 4 implies that the optimal sensitive capital requirements k_H and k_L are the same as in Proposition 1 because the bank H always keeps the project. In what follows, for exposition reasons, we disregard the case when the discount $\frac{\delta b}{1+\delta}$ is higher than $r_H - r_L$. In such a case, the regulator could punish the bank L with selling and would have more room to introduce sensitive capital requirements for some γ for which it is not possible when there is no secondary market. Despite this additional room to punish the main result of this section, Lemma 4, is unaffected: Under sensitive capital requirements the regulator eliminates the bank's incentive to sell contrary to the case of insensitive capital requirements, where the regulator may want to encourage it as in case 1 of Lemma 3.

3.3 Optimal capital requirements

The next proposition describes the regulator's choice between the insensitive and sensitive capital requirements when the secondary market exists.

Proposition 2 *Suppose there is a secondary market for the bank's project and* $\frac{\delta b}{1+\delta} \leq r_H - r_L$. *The optimal* $k_H^S = k_L^S = 1$ *if* $k_H = k_L$ *or* $k_H^S > 1 + k_H - \underline{k_H}$ *and* $k_L^S \geq 1$ *if* $k_H < k_L$. *The optimal* $s = 0$. *For* $\pi \in \left[\max\left\{\pi_0; \frac{1}{1+\delta}\right\}; \pi_C\right)$ *and* $\underline{k_L} \in \left(\underline{k_H}; \min\left\{1; \frac{1+\delta+\underline{k_H}+C}{2+\delta}\right\}\right)$ *as well as each* $\gamma \in (1/2; 1)$ *and* $\delta \in (0; r_L)$, *there exist a function* $m_S(\gamma)$, *thresholds* γ_{1S} *and* $\underline{k_L}'$ *as well as* q *and* x *satisfying (7)-(10) such that social welfare is maximized if:*

1. $k_H = k_L \geq k_{P2}$ *for* $m > m_S(\gamma)$;
2. $k_H = \underline{k_L} - \frac{\gamma\delta(1-\underline{k_L})}{(1-\gamma)(1+\delta)} > \underline{k_H}$ *and* $k_L = \underline{k_L}$ *for* $m \in (0; m_S(\gamma))$, $\gamma \in [\gamma_{1S}; \gamma_2)$ *and* $\underline{k_L} > \underline{k_L}'$;
3. $k_H = \underline{k_H}$ *and* $k_L = \underline{k_L}$ *for* $m \in (0; m_S(\gamma))$ *and* $\gamma \in [\max[\gamma_{1S}; \gamma_2]; 1)$.

$m_S(\gamma)$ *is* 0 *for* $\gamma \leq \gamma_{1S}$ *as well as positive and increasing in* γ *for* $\gamma \in (\gamma_{1S}; 1)$. *It holds that* $\gamma_{1S} > \gamma_1$, $\underline{k_L}' > \underline{k_H} + (1-\gamma_1)\left(1 - \underline{k_H}\right)$ *and* $m_S(\gamma) < m(\gamma)$ *for any* $\gamma > \gamma_1$.

For any other π or $\underline{k_L}$ *the solution for* k_H*,* k_L*,* q*, and* x *is the same as in Proposition 1.*

Proof. See Appendix A. ■

Proposition 2 is an immediate consequence of Lemma 3, 4 and 5. For π such that the secondary market does not provide any social benefit under insensitive capital requirements, the optimal choice of capital requirements is the same as in Proposition 1. For $\pi \in \left[\max\left\{\pi_0; \frac{1}{1+\delta}\right\}; \pi_C\right)$ and $\underline{k_L} \in \left(\underline{k_H}; \min\left\{1; \frac{1+\delta+\underline{k_H}+C}{2+\delta}\right\}\right)$ the insensitive capital requirements become more socially desirable with respect to the sensitive capital requirements. The reason is that the secondary market under the insensitive capital requirements reduces the bank H's burden by allowing for more efficient use of capital, which is not possible under the sensitive capital requirements. Formally, the threshold for inspection cost m for which the insensitive capital requirements deliver higher welfare becomes lower as expressed by $m_S(\gamma) < m(\gamma)$ for any $\gamma > \gamma_1$ as shown in Figure 5.

4 Discussion

4.1 Stochastic returns

So far we have assumed that the project i's return is certain if the bank monitors. In this section, we discuss the case of the stochastic returns and present the formal treatment in Appendix B. For simplicity, we assume that the project's returns are binary if the bank monitors: The project either succeeds or fails. The bank's projects differ in a probability of failure, which is the bank's private information.

The first consequence is that the regulator may charge the bank that monitors with deposit insurance premia covering the deposit claims in case of the bank's default. Appendix B shows that this extension does not deliver any additional insights to the model.

The second consequence is an additional and positive effect of the secondary market on social welfare. If probability of failure is positive for at least one project, the sale of such a project to the investors eliminates a possibility of incurring social cost of bank default C for *any* capital requirements chosen by the regulator (Duffie (2007) and Acharya et al (2010) point out that the credit risk transfer may be socially efficient because it leads to diversification of risk and increase in financial stability). First, the result from Lemma 4 where the regulator eliminates the bank H's incentive to sell obtains only for sufficiently low C. The reason is that the social benefit of the secondary market is now higher because the project's sale not only lowers the bank's burden from capital requirements but it also eliminates the possibility of socially costly bank's default. Hence, if C is sufficiently high, the bank is allowed to sell under sensitive capital requirements and some restrictions preventing unravelling of the truthtelling incentives. However, the result from Proposition 2 that the insensitive capital requirements become more socially desirable when the secondary market exists becomes even stronger.[43] The insensitive capital requirements allow for the realization of both positive effects of the secondary market, whereas the sensitive capital requirements result either in bank keeping the project at the expense of a possible bank's default for low C or in elimination of this cost at the expense of higher cost of inspection and penalty for high C.

4.2 Case of uninsured depositors

Throughout the paper we have assumed that the bank raises only insured deposits. Now we discuss the case of uninsured deposits. An unregulated bank can attract such deposits only if it commits enough capital to monitor. Although uninsured deposits are a source of market discipline there is still scope for regulatory intervention for two reasons. First, neither the bank nor the investors internalize social cost of the bank's default, which may result in the bank attracting deposits by making a socially inefficient monitoring decision. Second, the regulator can ensure that the capital is used more efficiently by imposing sensitive capital requirements and therefore providing the depositors with information about i that will be reflected in the deposit rate paid by the bank. In the baseline model, the deposit rate for i is 0 because of the deterministic return. Under stochastic returns the deposit rates will reflect the difference in the banks' probability of failure in the same way as the fair deposit insurance premia reflect it when the deposits are insured. Hence, the paper's results do not depend on the case whether deposits are insured or uninsured.

[43] We leave out details of the formal argument because they are similar to the ones presented in the paper.

4.3 Additional agency problems

So far we have assumed that the bank's shareholders are the sole suppliers of capital and bank managers. Here we discuss consequences of relaxing this assumption. First, if we allow for outside shareholders, the incentive to misreport for the bank L is higher than under inside equity. The reason is that for a given amount of capital injected into the bank, the outside shareholders require a smaller share of profits from the bank H than from the bank L whose project is less valuable. Hence, by mimicking the bank H the bank L can sell the outside shareholders a share of its profits smaller than it would if its type was known.[44] This would tighten the truthtelling constraint of the bank L in comparison with the case of inside capital and would lead to a lower social welfare from sensitive capital requirements because the regulator would have to inspect and punish more often. However, this effect is not as detrimental to the incentive to reveal the true type as the effect of the project's sale. The reason is that the bank L still keeps the project on its books.

Second, the assumption that shareholders manage the bank assumes away a conflict of interests between the bank's shareholders and the hired manager. The shareholders who want to maximize their return on capital would be interested in misreporting. However, the manager might be interested in truthful reporting, say, for career concern reasons. Hence, misreporting arises when the shareholders provide the manager with a compensation contract that aligns interests of both parties. In such a case, the problem boils down to the one studied in the baseline model. If the regulator could influence compensation contracts or impose sufficiently high penalties on the managers, misreporting would not arise (John et al. (2000) provide a rationale for including the managerial compensation in the bank regulation).

4.4 Regulatory forbearance

We have assumed in the baseline model that the regulator can commit to inspection and penalty. However, commitment of that sort is often seen as unrealistic in the banking context

[44] Once the new shareholders aquire the bank's shares, their own and old shareholders' interests are the same implying that capital requirements are unaffected by a division of the returns between shareholders. If α is a share of the bank owned by a shareholder, the shareholder receives $\alpha(r_i + k)$ if the project is monitored or αb if not. Hence, every shareholder makes the same monitoring decision regardless of its stake in the bank.

due to so-called regulatory forbearance. In our model, regulatory forbearance would mean that the regulator has no incentive to conduct costly inspection and order costly recapitalization (see Huizinga and Laeven (2010) for evidence on such forbearance).

The easiest way to model the regulatory forbearance is to assume that the regulator cannot commit to the inspection but the bank is punished whenever the report is different than the result of inspection. Because the regulator decides whether to inspect after the bank's report, the game between the bank and the regulator may have an equilibrium in mixed strategies in the regulator's inspection and the bank L's misreporting (Khalil (1997)). Because the bank L misreports with some probability, it will also default with some probability imposing social cost C. Hence, the insensitive capital requirements become more socially desirable because they eliminate regulatory forbearance given that they do not require inspection and recapitalization as penalty. This result is even stronger when there is a secondary market. The reason is that the regulator is even less willing to inspect and order recapitalization because the possible default of the bank L can also be avoided by allowing the bank to sell.

4.5 Policy implications

In our model, sensitive capital requirements become detrimental to the bank's incentive to misreport when the bank can sell its project, even if the regulator uses all of the available means to inspect and punish the misreporting bank. In the context of the model, a limit on dividends paid out to shareholders that is sufficiently high to prevent the bank H from selling would restore the bank's incentive to misreport. In an extended framework, measures such as retention of part of the sold project (if the project would be divisible) or an increase in capital requirements (if there were additional investment opportunities within the bank) would serve as equivalent instruments.

Moreover, insensitive capital requirements become more socially desirable than sensitive capital requirements for two reasons. First, insensitive capital requirements eliminate the problem of bank undercapitalization because they do not rely on bank's reporting. Second, the bank can reduce its burden from such a high capital requirement by selling its assets on the secondary market. Finally, the paper suggests that the sensitivity of capital requirements might depend on the liquidity of the bank assets: with sensitive capital requirements for assets that are not easily sold (such as loans to small business finance) and high insensitive capital requirements for assets that can be easily sold (such as mortgages).

5 Conclusions

The paper derives socially optimal sensitivity of bank capital requirements when the value of the bank's project and actions are the bank's private information. It is done under two scenarios: without and with the secondary market for the bank's project. We show that the secondary market is crucial for the bank's incentive to reveal the value of its project. Sensitive capital requirements become less socially desirable if the bank can sell its project without any constraints. The reason is that the bank's incentive to misreport is greater when the bank can sell its assets instead of keeping it. The results of the paper have important consequences for the current overhaul of the bank capital regulation. We show that a combination of risk-based capital requirements and a leverage ratio like in the Basel III Accord can be detrimental for the truthful revelation of the bank's private information when the bank can sell its project. We propose to introduce a high and uniform capital requirement for all banks.

6 References

Acharya, V., Philippon, T., Richardson, M., Roubini, N., 2009. The Financial Crisis of 2007-2009: Causes and Remedies. In: Acharya, V., Richardson, M., editors. *Restoring Financial Stability: How to Repair a Failed System.* New York University Stern School of Business/John Wiley & Sons.

Acharya, V, Schnabl, P., Suarez, G., 2010. Securitization Without Risk Transfer. Working paper.

Acharya, V., Yorulmazer, T., 2008. Cash-in-the-Market Pricing and Optimal Resolution of Bank Failures. Review of Financial Studies. 21, 2705-2742.

Aghion, P., Bolton, P., Fries, S., 1999. Optimal Design of Bank Bailouts: The Case of Transition Economies. Journal of Institutional and Theoretical Economics. 155, 51-70.

Allen, F., Carletti, E., Marquez, R., 2011. Credit Market Competition and Capital Regulation. Review of Financial Studies. 24, 983-1018.

Basel Committee on Banking Supervision, 2004. International Convergence of Capital Measurement and Capital Standards. Bank For International Settlements, Basel, Switzerland.

Berger, A., Davies, S., 1998. The Information Content of Bank Examinations. Journal of Financial Services Research. 14, 117-144.

Berger, A., Davies, S. M. , Flannery, M., 2000. Comparing Market and Supervisory Assessments of Bank Performance: Who Knows What When?, Journal of Money, Credit and Banking 32, 641-67.

Berger A., Udell G., 1993. Securitization, Loan Sales, and the Liquidity Problem in Banking. In: Klausner M., White L. J., editors. *Structural Change in Banking.* Irwin, IL: Homewood.

Blum, J., 2008. Why Basel II May Need a Leverage Ratio Restriction. Journal of Banking and Finance. 32, 1699-1707.

Bruche and Llobet (2011). Walking Wounded or Living Dead? Making Banks Foreclose Bad Loans, CEMFI working paper.

Cerasi, V., Rochet, J.-C., 2008. Solvency Regulation and Credit Risk Transfer. Working paper.

CGFS. 2009. The Role of Valuation and Leverage in Pro-cyclicality. CGFS Papers No. 34.

Dahiya, S., M. Puri, and A. Saunders, 2003. Bank Borrowers and Loan Sales: New Evidence on the Uniqueness of Bank Loans. Journal of Business 76 (4).

Demsetz R.,2000. Bank Loan Sales: A New Look at the Motivations for Secondary Market Activities. Journal of Financial Research, 23, 192-222.

DeYoung, R., Flannery, M., Lang, W., Sorescu, S., 2001. The Information Content of Bank Exam Ratings and Subordinated Debt Prices. Journal of Money, Credit, and Banking 33, 900-925.

Diamond, D., Rajan, R. 2000. A Theory of Bank Capital. Journal of Finance. LV, 2431-2465.

Drucker, S., Puri, M., 2009. On Loan Sales, Loan Contracting, and Lending Relationships. Review of Financial Studies 22, 2835-2872.

Duffie, D., 2007. Innovations in Credit Risk Transfer: Implications for Financial Stability. Working paper.

Flannery, M., Houston, J. F., 1999. The Value of a Government Monitor for U.S. Banking Firms. Journal of Money, Credit, and Banking 31, 4-34.

Gorton, G., Pennacchi, G., 1995. Banks and loan sales marketing nonmarketable assets, Journal of Monetary Economics 35, 389–411.

Gorton, G., Winton, A., 2000. Liquidity Provision, Bank Capital, and the Macroeconomy. Working paper.

Gunther, J., Moore, R., 2003. Loss Underreporting and the Auditing Role of Bank Exams. Journal of Financial Intermediation. 12, 153-177.

Holmstrom, B., Tirole, J., 1997. Financial Intermediation, Loanable Funds and the Real Sector. Quarterly Journal of Economics. 112, 663-691.

Huizinga, H., Laeven, L., 2009. Accounting Discretion of Banks During a Financial Crisis. CEPR working paper 7381.

IMF, 2008. Global Financial Stability Report April 2008.

John, K., Saunders, A., Senbet, L.W., 2000. A Theory of Bank Regulation and Management Compensation. Review of Financial Studies. 13, 95-125.

Khalil, F., 1997. Auditing Without Commitment. RAND Journal of Economics. 28, 629-640.

Marsh, I. 2006. The Effect of Lenders' Credit Risk Transfer Activities on Borrowers' Equity Returns. Working Paper, Bank of Finland Research Discussion Papers.

McLean, B. 2011. Did Accounting Help Sink Corzine's MF Global?. Reuters, Nov 1, 2011. http://blogs.reuters.com/bethany-mclean/2011/11/01/did-accounting-help-sink-corzines-mf-global/

Mitchell, J., 2001, Bad Debts and the Cleaning of Banks' Balance Sheets: An Application to Transition Economies. Journal of Financial Intermediation, 10, 1-27.

Morgan, D., 2002. Rating Banks: Risk and Uncertainty in an Opaque Industry. American Economic Review. 92, 874–888.

Morrison, A., White, L., 2005. Crises and Capital Requirements in Banking. American Economic Review. 95, 1548-1572.

Nadauld, T., Sherlund, S., 2008. The Role of the Securitization Process in the Expansion of Subprime Credit, Working Paper, Ohio State University.

Parlour, C., Plantin, G., 2008. Loan Sales and Relationship Banking. Journal of Finance. 63, 1291-1314.

Parlour, C., Winton, A., 2008. Laying of Credit Risk: Loan Sales versus Credit Default Swaps. Working Paper.

Pennacchi, G., 1988. Loan sales and the cost of bank capital, The Journal of Finance 43, 375–396.

Perstiani, S., Morgan, D., and Savino, V., 2010. The Information Value of the Stress Test and Bank Opacity. FRB of NY Staff Report No. 460.

Prescott, E. S., 2004. Auditing and bank capital regulation. Economic Quarterly, Federal Reserve Bank of Richmond. 90/4, 47-63.

Rajan, R., 1992. Insiders and Outsiders: The Choice Between Informed and Arm's-length Debt, The Journal of Finance 47, 1367–1400.

Rochet, J.-C., 2004. Macroeconomic Shocks and Banking Supervision. Journal of Financial Stability. 1, 93-110.

Saunders, A., Cornett, M., 2006. Financial Institutions Management: A Risk Management Approach (McGraw-Hill).

Shapiro, M. 2010. Testimony Concerning the Lehman Brothers Examiner's Report Before the House Financial Services Committee.

von Thadden, E.-L., 2004. Asymmetric Information, Bank Lending, and Implicit Contracts: The Winner's Curse, Finance Research Letters 1, 11-23.

Valukas, A., 2010. Lehman Brothers Holdings Inc. Chapter 11 Proceedings Examiner's Report.

Van den Heuvel, S., 2008. The welfare cost of bank capital requirements. Journal of Monetary Economics. 55, 298-320.

Vaughan, L., 2011. Financial Alchemy Foils Capital Rules as Banks Redefine Risk. Bloomberg, Nov 9, 2011. http://www.bloomberg.com/news/2011-11-09/financial-alchemy-undercuts-capital-regime-as-european-banks-redefine-risk.html

7 Appendix A - Proofs

Proof of Proposition 1

The maximization problem (5)-(10) can be simplified by making five observations. First, optimal k_L is $\underline{k_L}$, because setting $k_L > \underline{k_L}$ decreases social welfare and strengthens the bank L's incentive to misreport its type. Second, it has to hold that $k_H \leq \underline{k_L}$, because for $k_H > \underline{k_L}$ the bank H would prefer to report L. Third, it has to hold that $x \geq \underline{k_L} - k_H$ so that the bank L monitors the project if punished. Suppose that $x < \underline{k_L} - k_H$. Because the punished bank L earns b, the truthtelling constraint for the bank L does not hold, because it reads $r_L - \delta k_L \geq b - k_H(1+\delta) - q\gamma(1+\delta)x$, which is equivalent to $x \geq \frac{\underline{k_L} - k_H}{q\gamma} > \underline{k_L} - k_H$ and contradicts $x < \underline{k_L} - k_H$. Fourth, (7) has to bind. Otherwise the regulator would increase social welfare by lowering x or q. This implies together with $k_L = \underline{k_L}$ that (7) boils down to $x = \frac{1+\delta-q\gamma}{q\gamma\delta}(\underline{k_L} - k_H)$. Fifth, (8) can be ignored because it is slack when the regulator finds optimal to set sensitive capital requirements. Suppose that optimal $k_H < \underline{k_L}$, as well as q and x were such that (8) would bind. Then $k_H < \underline{k_L}$ is not optimal because the regulator could increase social welfare by setting $k_H = k_L = \underline{k_L}$ and $q = x = 0$, which would keep the bank H's payoff the same and save on implementation cost.

After using all the observations, inserting $x = \frac{1+\delta-q\gamma}{q\gamma\delta}(\underline{k_L} - k_H)$ into W_1 and into (9) as well as ignoring constants in W_1 the maximization problem (5)-(10) boils down to:

$$\max_{k_H, q} \frac{1-\gamma-\delta(2\gamma-1)}{\gamma} k_H + q((1-\gamma)(\underline{k_L} - k_H) - m) \tag{11}$$

subject to

$$\underline{k_L} \geq k_H \geq \underline{k_H}, 1 \geq q \geq \widetilde{q}(k_H) \equiv \frac{1}{\gamma} \frac{(\underline{k_L} - k_H)(1+\delta)}{\underline{k_L} - k_H + \delta(1-k_H)}. \tag{12}$$

The lower bound on q comes from inserting $x = \frac{1+\delta-q\gamma}{q\gamma\delta}(\underline{k_L} - k_H)$ into (9). We divide the analysis into two cases: (1) $\gamma \in \left(\max\left[1/2; \frac{(r_H - r_L)(1+\delta)}{r_H - r_L + \delta(1-\underline{k_H})}\right]; 1\right)$ and (2) $\gamma \in \left(1/2; \frac{(r_H - r_L)(1+\delta)}{r_H - r_L + \delta(1-\underline{k_H})}\right]$. The last interval is not empty if $\underline{k_L} > \underline{k_H} + \frac{\delta}{1+2\delta}\left(1 - \underline{k_H}\right)$.

Case (1): $\gamma \in \left(\max\left[1/2; \frac{(r_H - r_L)(1+\delta)}{r_H - r_L + \delta(1-\underline{k_H})}\right]; 1\right)$. For this set of parameters it holds that $1 > \widetilde{q}(\underline{k_H})$, i.e., $k_H = \underline{k_H}$ is feasible.

Claim The maximization problem (11)-(12) has only one of three solutions: (i) $k_H = \underline{k_H}$ and $q = \widetilde{q}(\underline{k_H})$, (ii) $k_H = \underline{k_H}$ and $q = 1$, or (iii) $k_H = \underline{k_L}$ and $q = 0$.

Proof. First, the optimal q is either 1 or $\widetilde{q}(k_H)$, because (11) is linear in q for any k_H. Second, for $q = 1$, the solution is either $k_H = \underline{k_H}$ or $k_H = \underline{k_L}$, because (11) is linear in k_H. Third, for $q = \widetilde{q}(k_H)$, the solution is again either $k_H = \underline{k_H}$ or $k_H = \underline{k_L}$, because (11) is convex in k_H. To show that (11) is convex in k_H for $q = \widetilde{q}(k_H)$, it suffices to insert $q = \widetilde{q}(k_H)$ in (11) and take the second order derivative with respect to k_H, which is $\frac{2(1-\underline{k_L})\pi\delta(1+\delta)\left[(1-\underline{k_L})(1-\gamma)\delta + m(1+\delta)\right]}{\gamma\left(\underline{k_L} - k_H + \delta(1-k_H)\right)^3}$ and positive for any $k_H \in \left[\underline{k_H}; \underline{k_L}\right]$. This also implies that $q = 0$ for $k_H = \underline{k_L}$. Fourth, the solution $k_H = \underline{k_L}$ and $q = 1$ delivers lower value of the objective function than $k_H = \underline{k_L}$ and $q = 0$. These four observations imply the claim. ■

Which of the three solutions (i)-(iii) delivers higher welfare is determined by comparing the values of (11) at the respective solutions. First, $k_H = \underline{k_H}$ with $q = \widetilde{q}(\underline{k_H})$ delivers higher welfare than $k_H = \underline{k_H}$ with $q = 1$ for $m > (1-\gamma)(r_H - r_L) \equiv m_{12}$. Second, $k_H = \underline{k_L}$ yields higher welfare than $k_H = \underline{k_H}$ with $q = 1$ for $m > \max[m_1; 0]$, where $m_1 \equiv \left[\delta - \frac{(1-\gamma)^2}{(2\gamma-1)}\right] \frac{(r_H - r_L)(2\gamma - 1)}{\gamma}$, and than $k_H = \underline{k_H}$ with $q = \widetilde{q}(\underline{k_H})$ for $m > \max[m_2; 0]$, where $m_2 \equiv \delta\left[\frac{\gamma(r_H - r_L)}{1+\delta} + (1 - \underline{k_H})\left(\frac{\gamma(1+2\delta)}{1+\delta} - 1\right)\right]$. Simple algebra shows that $m_1 = m_2 = m_{12} = \frac{\delta(r_H - r_L)}{1+2\delta} > 0$ for $\gamma = \frac{1+\delta}{1+2\delta}$. Hence, $k_H = \underline{k_L}$ and $q = 0$ yields the highest welfare for $m > \max[0; m_1]$ if $\gamma < \frac{1+\delta}{1+2\delta}$ and $m > m_2$ if $\gamma \geq \frac{1+\delta}{1+2\delta}$. Taking derivatives of m_1 and m_2 with respect to all parameters shows that m_1 and m_2 are increasing in γ ($\frac{\partial m_1}{\partial \gamma} = \frac{2(r_H - r_L)(1-\gamma)}{2\gamma - 1} + \left[\delta - \frac{(1-\gamma)^2}{(2\gamma-1)}\right] \frac{r_H - r_L}{\gamma^2} > 0$ and $\frac{\partial m_2}{\partial \gamma} = \delta\left[\frac{r_H - r_L}{1+\delta} + (1 - \underline{k_H})\frac{1+2\delta}{1+\delta}\right] > 0$).

Case (2): $\gamma \in \left(1/2; \frac{(r_H - r_L)(1+\delta)}{r_H - r_L + \delta(1-\underline{k_H})}\right]$. For this set of parameters it holds that $\widetilde{q}(\underline{k_H}) > 1$. Hence, for $k_H = \underline{k_H}$ there are no $q \in [0;1]$ and $x \leq 1 - k_H$ for which (7) holds. The lowest k_H for which (7) holds for $q = 1$ and $x = 1 - k_H$ is $k_H = \underline{k_L} - \frac{\gamma\delta(1-\underline{k_L})}{(1-\gamma)(1+\delta)} \equiv k_H^{LR}$. The set of constraints for maximization of (11) becomes: $\underline{k_L} \geq k_H \geq k_H^{LR}, 1 \geq q \geq \widetilde{q}(k_H)$. Using the similar chain of arguments as in the proof of the above claim we can show that this time there are two possible solutions: $k_H = k_H^{LR}$ and $q = 1$, or $k_H = \underline{k_L}$ and $q = 0$. Comparing the values of (11) at the respective solutions shows that $k_H = \underline{k_L}$ and $q = 0$ yields higher welfare for $m > \max[m_{lr}; 0]$, where $m_{lr} \equiv \left[\delta - \frac{(1-\gamma)^2}{(2\gamma-1)}\right] \frac{\delta}{1+\delta} \frac{2\gamma-1}{1-\gamma} \left(1 - \underline{k_L}\right)$. Moreover, $m_{lr} \geq 0$ for $\gamma \in \left[1 + \delta - \sqrt{\delta(1+\delta)}; 1\right]$, where $\gamma = 1 + \delta - \sqrt{\delta(1+\delta)}$ is the lower bound of the solution to $\delta - \frac{(1-\gamma)^2}{(2\gamma-1)} \geq 0$, which determines if $m_{lr} \geq 0$. $m_{lr} = m_1$ holds for $\gamma = \frac{(r_H - r_L)(1+\delta)}{r_H - r_L + \delta(1-\underline{k_H})}$. m_{lr} is increasing in γ ($\frac{\partial m_{lr}}{\partial \gamma} = \frac{\delta}{1+\delta}\left(1 + \frac{\delta}{1-\gamma}\right)\left(1 - \underline{k_L}\right) > 0$).

Denote $\gamma_1 = 1 + \delta - \sqrt{\delta(1+\delta)}$ and $\gamma_2 = \frac{(r_H - r_L)(1+\delta)}{r_H - r_L + \delta(1-\underline{k_H})}$. Using all the properties derived above, we can define a piecewise and continuous function $m(\gamma)$ such that

$$m(\gamma) = \begin{cases} 0, \ \gamma \in \left(\frac{1}{2}; \gamma_1\right) \\ m_{lr}, \ \gamma \in [\gamma_1; \gamma_2) \ \text{ if } \gamma_1 < \gamma_2 \\ m_1, \ \gamma \in \left[\max[\gamma_1; \gamma_2]; \frac{1+\delta}{1+2\delta}\right) \ \text{ if } \gamma_2 < \frac{1+\delta}{1+2\delta} \\ m_2, \ \gamma \in \left[\max\left[\gamma_2; \frac{1+\delta}{1+2\delta}\right]; 1\right). \end{cases}$$

Moreover, for any $\delta > 0$ it holds that $\frac{1}{2} < \gamma_1 < \frac{1+\delta}{1+2\delta} < 1$ and $\gamma_2 < 1$. Hence, the ultimate shape of $m(\gamma)$ depends on the parameters, which determine the position of γ_2. If $\gamma_2 \leq \gamma_1$, the part with m_{lr} is missing. If $\gamma_1 < \gamma_2 < \frac{1+\delta}{1+2\delta}$, $m(\gamma)$ consists of all four parts. If $\frac{1+\delta}{1+2\delta} \leq \gamma_2$, the part with m_1 is missing.

We conclude that $k_H = k_L = \underline{k_L}$ and $q = x = 0$ is the solution to the regulator's maximization problem (5)-(10) for $m > m(\gamma)$. $k_H = \underline{k_L} - \frac{\gamma\delta(1-\underline{k_L})}{(1-\gamma)(1+\delta)} > \underline{k_H}$, $k_L = \underline{k_L}$ with $q = 1$ and $x = \frac{(1+\delta-\gamma)\left(1-\underline{k_L}\right)}{(1-\gamma)(1+\delta)}$ is the solution for $m \in (0; m(\gamma))$ and $\gamma \in [\gamma_1; \gamma_2)$ if $\gamma_1 < \gamma_2$, which is equivalent to $\underline{k_L} > \underline{k_H} + (1-\gamma_1)\left(1 - \underline{k_H}\right)$. We observe that $\underline{k_H} + (1-\gamma_1)\left(1 - \underline{k_H}\right) \in \left(\underline{k_H}; 1\right)$. $k_H = \underline{k_H}$ and $k_L = \underline{k_L}$ supported by $q = 1$ and $x = \frac{(1+\delta-\gamma)\left(\underline{k_L} - \underline{k_H}\right)}{\delta\gamma}$ or $q = \frac{1}{\gamma}\frac{(r_H - r_L)(1+\delta)}{r_H - r_L + \delta(1-\underline{k_H})}$ and $x = 1 - \underline{k_H}$ are the solution for the rest of parameters, i.e., $m \in (0; m(\gamma))$ and $\gamma \in (\max[\gamma_1; \gamma_2]; 1)$.

Proof of Lemma 2

We prove the lemma in four steps.

Step 1: The highest pooling price the investors can offer is $P_1 = 1 + \pi r_H + (1-\pi) r_L - \delta\frac{b + \pi(r_H - r_L)}{1+\delta}$ for $\pi \in (0; \pi_0)$ and $P_2 = \pi(1 + r_H) + (1-\pi)b - \frac{\delta b}{1+\delta}$ for $\pi \in [\pi_0; \pi_C)$.

Proof: The constraints on P and e for the cases when the investors anticipate each bank i to sell are derived in the text. Because the investors are competitive both constraints have to bind. If the incentive compatibility constraint is slack and the participation constraint binds the investors can increase P and lower e and still attract deposits. If the incentive compatibility constraint binds and the participation constraint is slack, the investors can increase both P and e and still make a profit. Hence, the competitive investors set e and raise P until both constraints bind. The investors offer $P_1 = 1 + \pi r_H + (1-\pi) r_L - \delta \frac{b+\pi(r_H - r_L)}{1+\delta}$ and invest capital $\frac{b+\pi(r_H-r_L)}{1+\delta}$ if they commit to monitor both projects or $P_2 = \pi(1+r_H) + (1-\pi)b - \frac{\delta b}{1+\delta}$ and invest capital $\frac{b}{1+\delta}$ if they commit to monitor only the project H. Comparing P_1 and P_2 shows that $P_1 < P_2$ holds for $\pi \in (0;\pi_0)$ and $P_2 \geq P_1$ for $\pi \in [\pi_0;\pi_C)$. $P_2 \geq P_1$ holds for any $\pi \in [\pi_0; 1)$ but we restrict the parameter space for π only to π_C due to (4).■

Step 2: The pooling outcome in which each bank i sells the project arises exists for $k \geq k_{P1} + k^S - 1$, $k^S \leq 2 - k_{P1}$ if $\pi \in (0;\pi_0)$, where $k_{P1} = \underline{k_L} + \frac{(1-\pi)(r_H - r_L)}{\delta}$, or for $k \geq k_{P2} + k^S - 1$, $k^S \leq 2 - k_{P2}$ and $\pi \in [\pi_0; \pi_C)$, where $k_{P2} = \underline{k_H} + \frac{(1-\pi)(1+\delta)\left(1-\underline{k_H}\right)}{\delta}$.

Proof: A pooling outcome exists if the bank H sells at a pooling price, i.e., pooling price is not lower than P_H^R. The inequality $P_1 \geq P_H^R$ is equivalent to $k \geq k_{P1} + k^S - 1$, and $P_2 \geq P_H^R$ to $k \geq k_{P2} + k^S - 1$. k_{P1} and k_{P2} cross at $\pi = \pi_0$ and $k_{P1} < k_{P2}$ for $\pi \in (0;\pi_0)$. Because k is bounded from above by 100% equity financing, i.e., $k \leq 1$, the pooling outcome exists if $k_{P1} \leq 1$ or $k_{P2} \leq 1$, which are equivalent to $k^S \leq 2 - k_{P1}$ or $k^S \leq 2 - k_{P2}$.■

Step 3: Only the bank L sells the project for $k \in \left[\underline{k_L} + k^S - 1; \min\left[\min\left[k_{P1}; k_{P2}\right] + k^S - 1; 1\right]\right)$ and k^S such that the interval is not empty.

Proof: If k and k^S are such that the conditions derived in Step 2 do not hold, the bank H does not sell the project. The investors anticipate it so they infer that only the bank L would be ready to sell and they offer the highest possible price for the project L, $1 + r_L - \frac{\delta b}{1+\delta}$ and invest $\frac{b}{1+\delta}$ (again the investors' constraints derived in the text for the case when only the bank L is anticipated to sell are binding). The bank L sells if the price for its project is not lower than its reservation price P_L^R. $1 + r_L - \frac{\delta b}{1+\delta} \geq P_L^R$ is equivalent to $k \geq \underline{k_L} + k^S - 1$. Hence, only the bank L sells its project if

$$k \in \left[\underline{k_L} + k^S - 1; \min\left[\min\left[k_{P1}; k_{P2}\right] + k^S - 1; 1\right]\right).$$

The upper bound of this interval is given by the thresholds derived in step 2. This interval is not empty if its lower bound is smaller than the upper bound. If $k_{P1} + k^S - 1$ is the upper bound, the interval is not empty for any k^S. If $k_{P2} + k^S - 1$ is the upper bound, the interval is not empty for $\pi < 1 - \frac{\delta(r_H - r_L)}{(1+\delta)\left(1-\underline{k_H}\right)}$. If 1 is the upper bound then the interval is not empty for $k^S \leq 2 - \underline{k_L}$.■

Step 4: None of the banks sells its project for any $k < \min\left[k_{P2}; \underline{k_L}\right] + k^S - 1$.

Proof: The claim follows directly from the result in Step 3. ■

Proof of Lemma 3

First, we derive the socially optimal insensitive capital requirements. Second, we show that restricting the regulator's choice to the insensitive capital requirements when $q = 0$ is without loss of generality.

Step 1: The optimal insensitive capital requirements are such that the following conditions are satisfied. k^S is 1. $k \geq k_{P2}$ for $\pi \in \left[\max\left\{\pi_0; \frac{1}{1+\delta}\right\}; \pi_C\right)$ and $\underline{k_L} \in \left(\underline{k_H}; \min\left\{1; \frac{1+\delta+\underline{k_H}+C}{2+\delta}\right\}\right)$. $k = \underline{k_L}$ otherwise.

Proof: Under insensitive capital requirements the regulator anticipates that the outcomes on the secondary market are such as in Lemma 2 for given k, k^S and π. First, we study the case for $\pi \in (0; \pi_0)$. For $k \in \left[k_{P1} + k^S - 1; 1\right]$ and $k_{P1} + k^S \leq 2$ both banks sell for the pooling price P_1. Social welfare consists of the expected bank's return, which is

$$(P_1 + k)(1+\delta) - 1 - k^S\delta - k(1+\delta) = P_1(1+\delta) - 1 - k^S\delta$$

because each bank i sells for the same price and faces the same k^S. For $k \in \left[\underline{k_L} + k^S - 1; \min\left[k_{P1} + k^S - 1; 1\right]\right)$ only the bank L sells and its return is

$$(P_L^* + k)(1+\delta) - 1 - k^S\delta - k(1+\delta) = r_L - \delta\underline{k_L} + \delta\left(1 - k^S\right).$$

The bank H's return is $r_H - \delta k$. For other k and k^S none of the banks sells so their returns are $r_i - \delta k$. We ignore the case $k < \underline{k_L}$, because the bank L would default, which is socially inefficient under (4) (observe that $k_{P1} > \underline{k_L}$ for any $\pi \in (0;1)$). The regulator chooses k and k^S to maximize social welfare

$$\begin{cases} \pi(r_H - \delta k) + (1-\pi)(r_L - \delta k), \text{ if } k \in \left[\underline{k_L}; \underline{k_L} + k^S - 1\right) \\ \pi(r_H - \delta k) + (1-\pi)\left[r_L - \delta\underline{k_L} + \delta\left(1 - k^S\right)\right], \text{ if } k \in \left[\underline{k_L} + k^S - 1; \min\left[k_{P1} + k^S - 1; 1\right]\right) \\ P_1(1+\delta) - 1 - k^S\delta, \text{ if } k \in \left[k_{P1} + k^S - 1; 1\right] \text{ and } k_{P1} + k^S \leq 2 \end{cases}$$

subject to $k^S \geq 1$. The regulator sets $k^S = 1$ because social welfare is decreasing in k^S where applicable. Moreover, observe that $(P_1 - 1)(1+\delta) = \pi\left(r_H - \delta\underline{k_L}\right) + (1-\pi)\left(r_L - \delta\underline{k_L}\right)$. Hence, social welfare boils down to

$$\begin{cases} \pi(r_H - \delta k) + (1-\pi)\left(r_L - \delta\underline{k_L}\right), \text{ if } k \in \left[\underline{k_L}; \min\left[k_{P1}; 1\right]\right) \\ \pi\left(r_H - \delta\underline{k_L}\right) + (1-\pi)\left(r_L - \delta\underline{k_L}\right), \text{ if } k \in \left[k_{P1}; 1\right] \text{ and } k_{P1} \leq 1. \end{cases}$$

Because the first part of social welfare is maximized for $k = \underline{k_L}$, the regulator is indifferent between $k = \underline{k_L}$ or any $k \in [k_{P1}; 1]$ if $k_{P1} \leq 1$. Hence, the regulator can achieve the highest possible welfare by simply imposing $k = \underline{k_L}$ and social welfare is the same as in the case of the insensitive capital requirement $\underline{k_L}$ without the secondary market.

For $\pi \in [\pi_0; \pi_C)$ social welfare in the pooling outcome is always higher than in the pooling equilibrium for $\pi \in (0; \pi_0)$, because $P_2 > P_1$. In the rest of the equilibria in which either only the bank L sells or none of the banks sells, the highest social welfare is the same as for $\pi \in (0; \pi_0)$ and is obtained for $k = \underline{k_L}$. Hence, for $\pi \in [\pi_0; \pi_C)$ social welfare is maximized when each bank sells for P_2 for any $k \geq k_{P2}$ if $k_{P2} \leq 1$, which is equivalent to $\pi \geq \frac{1}{1+\delta}$. The pooling outcome is feasible for any $\pi \in \left[\max\left[\pi_0; \frac{1}{1+\delta}\right]; \pi_C\right)$ if $\frac{1}{1+\delta} < \pi_C$, which is equivalent to $\underline{k_L} \in \left(\underline{k_H}; \min\left[1; \frac{1+\delta+\underline{k_H}+C}{2+\delta}\right]\right)$. For any other parameters the pooling outcome is not feasible and the best the regulator can do is to set $k = \underline{k_L}$.■

Now we show that sensitive capital requirements cannot deliver higher social welfare than the insensitive. We denote as W_0 social welfare from the insensitive capital requirement $\underline{k_L}$. When the regulator imposes sensitive capital requirements there are two possibilities: either they are such that each bank reports its type truthfully or at least one bank misreports. The latter case is not interesting because it results in adverse selection as in the case of insensitive capital requirements. Hence, the optimal capital requirements are as described in Step 1 above. Hence, we are interested only in the case when sensitive capital requirements are such that each bank reports truthfully.

Step 2: Capital requirements for which a separating equilibrium with truthtelling may occur do not deliver higher welfare than W_0.

Proof: A separating equilibrium in which the bank i reports its type truthfully can exist only if the capital requirements are different so that investors can condition their offers on the choice of the capital requirements. To prove the claim from step 2 it suffices to analyze capital requirements such that the bank i's truthtelling conditions are satisfied. In a separating equilibrium there are four potential outcomes on the secondary market: each bank i sells/keeps, one bank sells and the other keeps.

First, observe that if k_i and k_i^S are such that in a separating outcome the bank H keeps the project, social welfare cannot be higher than W_0. The reason is that the regulator has to choose k_H that is not lower than $\underline{k_L}$, which delivers welfare not higher than W_0. Otherwise the bank L would find it profitable to mimic the bank H, keep the project (if the bank H finds it more profitable to keep the project, the same holds for the bank L whose project is less valuable than the project H) and default, which is socially inefficient due to (4).

Now observe the following. In a separating equilibrium with truthtelling the investors correctly infer the bank's type from the choice of capital requirements. Hence, the price offered for the project i, P_i, and the capital invested by the investors, e_i, have to be such that the investors' return on the monitored project after repaying deposits, $1 + r_i - (P_i - e_i)$, cannot be lower than the private benefits and the opportunity cost of capital: $1 + r_i - (P_i - e_i) \geq \max[b; (1+\delta) e_i]$. The investors offer the deposit rate of 0 because the monitored project always succeeds. The competitive investors offer $P_i^* = 1 + r_i - \frac{\delta b}{1+\delta}$ such that the last inequality is binding. The formal argument for binding constraints is identical to the one presented in the proof of Lemma 2. When the bank i reports truthfully and sells for the price P_i^*, its return at $t = 0$ is

$$V_i = \left(k_i^S - k_i\right) - (1 - k_i) + \left[P_i^* - \left(k_i^S - k_i\right)\right](1+\delta) - k_i (1+\delta) = r_i - \delta \underline{k_i} + \delta \left(1 - k_i^S\right). \qquad (13)$$

If the bank i deviates from the truthtelling and reports $j \neq i$, its return from such a misreporting is V_j.

Second, we analyze the case when each bank i sells. This requires that selling delivers higher return than keeping for each bank i, $V_i \geq r_i - \delta k_i$. The bank L reports its type truthfully if the return from reporting L and selling, V_L, is not lower than the payoff from reporting H and selling, V_H (keeping is worse than selling in case of misreporting because if selling is more profitable for the bank H, then it must also be for the bank L that pretends to be H): $V_L \geq V_H$. Now observe that it always holds that $V_L \leq r_L - \delta \underline{k_L}$. Hence, it implies that the bank H's return V_H in such a separating equilibrium the bank H is not higher than $r_L - \delta \underline{k_L}$. That is a lower return than in the case when the regulator simply imposes insensitive $\underline{k_L}$ and the bank H's return is $r_H - \delta \underline{k_L}$. Hence it follows that a separating equilibrium when each bank i sells is not socially efficient.

Finally, we analyze the case where the bank H sells and the bank L keeps. The bank L reports its type truthfully if its return from reporting L and keeping is not lower than reporting H and selling (keeping can be ignored for the same reason as above), $r_L - \delta k_L \geq V_H$,because the regulator imposes $k_L \geq \underline{k_L}$ due to (4). Hence, such an equilibrium would again deliver welfare lower than W_0 for the same reasons as above (for the bank H it holds that $V_H \leq r_L - \delta k_L \leq r_L - \delta \underline{k_L} < r_H - \delta \underline{k_L}$).■

Proof of Lemma 4

At the beginning we show that the truthtelling unravels when the regulator does not place any restrictions on the project's sale, i.e., $s = 1$ and $k_i^S = 1$. Suppose there is truthtelling for $k_H \in \left[\, \underline{k_H};\ \underline{k_L}\right)$ and $k_L \geq \underline{k_L}$.[45] The investors pay P_i^* when they see that the bank has capital level corresponding to report of i. Using the payoffs from selling at $t = \frac{1}{2}$ derived in the text, $k_i^S = 1$ and the expression for P_i^* we note that the bank H that is not punished has a payoff from selling equal to $r_H - \delta \underline{k_H} + k_H (1 + \delta)$ and the bank H that is punished, $r_H - \delta \underline{k_H} + (k_H + x)(1 + \delta)$ .At $t = 0$ once the opportunity cost of the initial investment k_H, $k_H (1 + \delta)$ and of potential recapitalization x, $x (1 + \delta)$, is taken into account, the return of the bank H at $t = 0$ whether it is punished or not is $r_H - \delta \underline{k_H}$. If the bank L anticipates at $t = 0$ that the bank H always sells its project, its expected return from misreporting at $t = 0$ is also $r_H - \delta \underline{k_H}$. Because it holds that $r_H - \delta \underline{k_H} > r_L - \delta \underline{k_L}$, the bank L always misreports if the bank H can sells its project in an unrestricted fashion.

Now in two steps we show that the regulator has to discourage the project's sale as a necessary condition for socially efficient sensitive capital requirements.

Step 1: For the bank L the optimal k_L and k_L^S are such that $k_L = \underline{k_L}$ and $k_L^S \geq 1$ or $k_L \geq \underline{k_L}$ and $k_L^S = 1$.

Proof: Suppose $k_H \in \left(\, \underline{k_H};\ \underline{k_L}\right)$ and $k_L \geq \underline{k_L}$. The regulator can relax the truthtelling constraint of the bank L when the bank L's payoff from revealing its type is the highest. Hence, the optimal k_L and k_L^S are such that $k_L = \underline{k_L}$ and $k_L^S \geq 1$ or $k_L \geq \underline{k_L}$ and $k_L^S = 1$. To see this observe that, if the bank L keeps its project, its return at $t = 0$ is $r_L - \delta k_L$. If it sells, its return at $t = 0$ is $r_L - \delta \underline{k_L} + \delta \left(1 - k_L^S\right)$. Hence, the regulator can achieve the highest possible return from truthtelling for the bank L, $r_L - \delta \underline{k_L}$, by imposing $k_L = \underline{k_L}$ and $k_L^S \geq 1$ or $k_L \geq \underline{k_L}$ and $k_L^S = 1$. To simplify the exposition we assume that the regulator simply chooses $k_L = \underline{k_L}$ and $k_L^S \geq 1$.■

Step 2: The optimal k_H^S is such that the bank H keeps the project, $k_H^S > 1 + k_H - \underline{k_H} - x$.

Proof: First, we show that the bank L has stronger incentive to misreport if the bank H sells than if it keeps the project. If the bank H sells, its return is $r_H - \delta \underline{k_H} + \delta \left(1 - k_H^S\right)$ and it is not lower than its return from keeping $r_H - \delta k_H$. Now if the bank L misreports, it gets the same return as the bank H if the bank H sells and it gets $b - (1 + \delta) k_H$ if the bank H keeps. Because it holds that $r_H - \delta k_H > b - (1 + \delta) k_H$ (it is equivalent to $k_H > \underline{k_H}$), then it has to hold that $r_H - \delta \underline{k_H} + \delta \left(1 - k_H^S\right) > b - (1 + \delta) k_H$. This implies that the bank L's payoff from misreporting if the bank H sells is higher than if the bank H keeps.

[45] For any $k_H \geq \underline{k_L}$ the bank L's incentive to misreport is not interesting because it always monitors if it mimicks. For any $k_i < \underline{k_i}$ the bank i keeps the project and defaults which is socially inefficient due to (4).

Second, we show that the regulator prefers to make the bank H that is not punished keep its project. The increased incentive to misreport tightens the truthtelling constraint of the bank L because the bank L's return from not being caught on misreporting increases when compared with case when the bank H keeps. Then the regulator is forced to spend more resources (higher q or x) on making the truthtelling constraint hold than in the case when the bank H keeps. Now, the regulator can improve social welfare by leaving the return of the bank H unchanged and relaxing the bank L's truthtelling constraint. The regulator can do so by increasing k_H^S and decreasing k_H in such a way that the bank H keeps the project and has the same return from keeping as from selling under old k_H^S, i.e., such k'_H that $r_H - \delta k'_H = r_H - \delta \underline{k_H} + \delta \left(1 - k_H^S\right)$. Under k'_H, if the bank L misreports, it cannot sell the project as the bank H, so its payoff from misreporting is $b - (1+\delta)\, k'_H$, for which it holds that

$$b - (1+\delta)\, k'_H < r_H - \delta k'_H = r_H - \delta \underline{k_H} + \delta \left(1 - k_H^S\right)$$

as long as $k'_H > \underline{k_H}$. This proves the claim that the regulator can increase welfare by keeping the bank H's payoff the same, but relaxing the truthtelling constraint of the bank L, which allows the regulator to save on the costly supervisory scheme. Observe that we can prove using the same arguments the claim that the regulator should set such k_H^S that the punished bank H does not have the incentive to sell either. Because the bank H that is punished is more willing to sell than if it is not punished we get the result that $k_H^S > 1 + k_H - \underline{k_H}$ is sufficient enough to eliminate the incentive to sell for the bank H whether it is punished or not.■

Proof of Lemma 5

Observe that once the regulator eliminates the bank's incentive to sell by making the bank keep a sufficiently high portion of the sale proceeds, the regulator can still nevertheless use selling as a penalty. The reason is that the project as can be seen from P_i^* sells at a discount to its fair value because of costly capital that the investors lay out. Whether selling is indeed a penalty for the bank L depends on the comparison of its return from being caught on misreporting if $s = 0$ and $s = 1$. If $s = 0$ then the bank L's return is the same as in (7), $r_L - \delta\,(k_H + x)$. If $s = 1$, the bank L after deviating from the truthtelling and being caught on misreporting sells as the bank H, because in the truthtelling equilibrium only the bank H is punished. Hence, the bank L's return for $s=1$ is

$$P_H^* - (1-k_H-x) - (1+\delta)(k_H+x) = r_H - \frac{\delta b}{1+\delta} - \delta(k_H+x).$$

If the bank L's return for $s=1$ is not lower than its return for $s=0$, the regulator will set $s=0$. The reason is that for $s=1$ the regulator would tighten the bank L's truthtelling constraint and decrease the bank H's return, which would lead to a decrease in social welfare. After comparing the returns this holds for $r_H - \frac{\delta b}{1+\delta} \geq r_L$. If $s=0$ then the constraints on sensitive capital requirements are the same as in Section 2, hence the regulator finds optimal the sensitive capital requirements as in Section 2.

For $r_H - \frac{\delta b}{1+\delta} < r_L$ $s=1$ is a penalty for the bank L. Again it is obvious that $s=1$ is not always optimal because it is also a welfare loss due to the bank H's decreased return. In fact, we can show that if the discount $\frac{\delta b}{1+\delta}$ is high enough, the regulator finds it optimal to set $s=1$. This will also lead to additional solutions for the sensitive capital requirements given that the additional penalty gives the regulator more scope to punish the bank. However, we do not provide the full derivation of this result, because it is very similar to the one presented in the proof of Proposition 1.■

Proof of Proposition 2

The optimal sensitive capital requirements are as in Proposition 1 because Lemma 4 and5 imply that the regulator's program for sensitive capital requirements is identical to the program (5)-(10) from Section 2. In order to determine whether the sensitive or insensitive capital requirements are optimal, we have to compare social welfare from both types of capital requirements.

For $\pi < \pi_0$ as well as $\pi \in [\pi_0; \pi_C)$ and other parameters such that the pooling outcome with P_2 is not feasible, the optimal insensitive capital requirements with the secondary market deliver the same welfare as the optimal insensitive capital requirements without the secondary market. Hence, the solution is the same as in the Proposition 1.

For $\pi \in \left[\max\left\{\pi_0; \frac{1}{1+\delta}\right\}; \pi_C\right)$ and $\underline{k_L} \in \left(\underline{k_H}; \min\left\{1; \frac{1+\delta+\underline{k_H}+C}{2+\delta}\right\}\right)$ such that the pooling outcome with P_2 arises, social welfare from the sensitive capital requirements has to be compared with social welfare from the insensitive capital requirements under the outcome that the bank sells for the pooling price P_2. We conclude that there is a new function $m_S(\gamma)$ such that it holds $m_S(\gamma) < m(\gamma)$ whenever $m(\gamma) > 0$. Moreover, $m_S(\gamma) < m(\gamma)$ implies that the thresholds as functions of γ that determine the parts of the function $m_S(\gamma)$ need to increase. It is straightforward because social welfare when the bank sells for a pooling price P_2 is higher than in the case without the secondary market, what was shown in Lemma 3. Now we derive $m_S(\gamma)$. The insensitive capital requirements deliver higher social welfare than the sensitive capital requirements with $k_H = \underline{k_H}$ for $m > \max\left[m_1 - z; m_2 - \frac{z}{\widetilde{q}(\underline{k_H};0)}; 0\right]$, where $z = (1+\delta)\left(1-\underline{k_L}\right)\frac{\pi-\pi_0}{\pi\pi_0}$. It holds that $m_1 - z > m_2 - \frac{z}{\widetilde{q}(\underline{k_H};0)}$ for $\gamma < \frac{1+\delta}{1+2\delta-\frac{z}{r_H-r_L}}$. The insensitive capital requirements deliver higher social welfare than the sensitive capital requirements with $k_H = k_H^{LR}$ for $m > \max[m_{lr} - z; 0]$. The inequality $m_{lr} - z \geq 0$ holds for $\gamma \in [\gamma_{1S}; 1]$, where $\gamma_{1S} = 1 + \delta + \frac{a}{2} - \sqrt{\delta(1+\delta) + \frac{a^2}{4} + a\delta}$ with $a = \frac{\delta}{1+\delta}\frac{\pi-\pi_0}{\pi\pi_0}$ and $\gamma_{1S} > \gamma_1$. $\gamma_{1S} > \gamma_1$ follows due to $a > 0$. Moreover, it holds that $\frac{1+\delta}{1+2\delta-\frac{z}{r_H-r_L}} \geq \frac{1+\delta}{1+2\delta}$ holds for $\pi \geq \pi_0$. Summarizing all results give us the following function:

$$m_S(\gamma) = \begin{cases} 0, \ \gamma \in \left(\frac{1}{2}; \gamma_{1S}\right) \\ m_{lr} - z, \ \gamma \in [\gamma_{1S}; \gamma_2) \ \text{ if } \gamma_{1S} < \gamma_2 \\ m_1 - z, \ \gamma \in \left[\max[\gamma_{1S}; \gamma_2]; \frac{1+\delta}{1+2\delta-\frac{z}{r_H-r_L}}\right) \ \text{ if } \gamma_2 < \frac{1+\delta}{1+2\delta} \\ m_2 - \frac{z}{\widetilde{q}(\underline{k_H};0)}, \ \gamma \in \left[\max\left[\gamma_2; \frac{1+\delta}{1+2\delta-\frac{z}{r_H-r_L}}\right]; 1\right). \end{cases}$$

To complete the claim we show that $\gamma_{1S} < \gamma_2$ holds for higher $\underline{k_L}$ than $\gamma_1 < \gamma_2$ holds. This follows from two facts: γ_2 is increasing in $\underline{k_L}$ and $\gamma_{1S} > \gamma_1$. Hence there is a threshold $\underline{k_L'} > \underline{k_H} + (1-\gamma_1)\left(1-\underline{k_H}\right)$ for which $\gamma_{1S} < \gamma_2$.

8 Appendix B - Change in the timing and stochastic returns

8.1 Change in timing and insured deposits

We allow for the following changes to the model presented in the paper: (i) the project's returns are stochastic, (ii) the bank learns i after it has financed the project. The timing of the model presented in the Figure 6 is as follows. At $t = 0$ the bank raises capital k_0 and insured deposits d_0. At $t = 1$ the bank receives a perfect signal about the type of the project i, can adjust its capital to k_i and deposits to d_i and decides whether to monitor it. At $t = 2$ the returns are realized. If the bank monitors, the project pays $1 + r$ at $t = 2$ with probability $1 - p_i$ or $1 - \lambda$ with probability p_i. p_i is called probability of default (PD) of the project i. If the bank doesn't monitor the project, the bank gets b and the project pays $1 - \lambda$ with probability 1. At $t = 0$ the probability that the project will be of type H (L) at $t = 1$ is π $(1 - \pi)$

and $p_H < p_L$. To simplify the exposition we assume that $\lambda = 1$. The cost of capital is δ at $t = 0$ and $t = 1$. The analogue of (1) is $(1 - p_L) r > \delta$.If the regulator knew i at $t = 1$ k_1 and d_1 would satisfy the following two conditions:

$$(1 - p_i)(1 + r - d_i) \geq b \text{ and } k_i + d_i = 1 + p_i d_i.$$

The first condition guarantees that the bank i monitor the project (deposits are insured and supplied at a deposit rate normalized to 0). The second condition is the balance sheet of the bank at $t = 1$, where the bank invests k_i and d_i in the project of size 1 and a fair deposit insurance premium $p_i d_i$. Because the capital is socially costly the regulator would like to set such d_i that the first condition binds. Hence, the minimum level of capital providing the bank i with an incentive to monitor, $\underline{k_i}$, and corresponding d_i are

$$\underline{k_i} = 1 + b - (1 - p_i)(1 + r) \text{ and } d_i = \frac{1 - \underline{k_i}}{1 - p_i}.$$

To justify the capital regulation we use an analogue of (2):

$$b > (1 - p_i)(1 + r) - 1,$$

which guarantees that $k_i > 0$. d_i is always positive because $(1 - p_i)(1 + r) > 1 > b$. Observe that $\underline{k_H} < \underline{k_L}$ because $p_H < p_L$. Hence, the minimum capital requirements increase with the probability of default p_i.

If the regulator does not observe i, the implementation of $\underline{k_H}$ and $\underline{k_L}$ is subject to the same adverse selection problem as in the baseline model. Hence, we proceed directly to the truthtelling constraints and show only the truthtelling constraint of the bank L:

$$\begin{aligned} & (1 - p_L)\left(1 + r - \frac{1 - \underline{k_L}}{1 - p_L}\right) - (1 + \delta)\left(\underline{k_L} - k_0\right) \\ \geq (1 - q\gamma)\left[b - (1 + \delta)(k_H - k_0)\right] \quad & + q\gamma\left[(1 - p_L)\left(1 + r - \frac{1 - k_H - x}{1 - p_H}\right) - (1 + \delta)(k_H + x - k_0)\right]. \end{aligned}$$

The constraint already takes into account that $k_H \leq \underline{k_L} \leq x + k_H$ has to hold, that the optimal k_L for the bank L is $\underline{k_L}$ and $d_i = \frac{1 - k_i}{1 - p_i}$. The right-hand side is the bank L's payoff from reporting L at $t = 1$. The first term is the payoff at $t = 2$ and the second term is the opportunity cost of adjustment of capital at $t = 1$ from k_0 to $\underline{k_L}$. The left-hand side is the bank L's expected payoff from misreporting at $t = 1$. The first term is the payoff in case the bank is not caught on misreporting with probability $1 - q\gamma$. The second term is the payoff when the bank L is punished with probability $q\gamma$. Because in the truthtelling equilibrium only the bank H is punished the regulator sets the deposit insurance premium for the bank caught on misreporting according to the PD of the bank H. Hence the bank L while deviating from truthtelling takes into account that it will be treated as the bank H when it is caught too, so its deposits after recapitalization are $\frac{1-k_H-x}{1-p_H}$. Solving the above constraint for x delivers:

$$x\left(\delta + \frac{p_L - p_H}{1 - p_H}\right) \geq \frac{p_L - p_H}{1 - p_H}(1 - k_H) + \left(\frac{1+\delta}{q\gamma} - 1\right)\left(\underline{k_L} - k_H\right). \tag{14}$$

The first observation is that (14) is slightly more complicated than the truthtelling constraint of the bank L (7) in the baseline model, which boils down to $x \geq \frac{1}{\delta}\left(\frac{1+\delta}{q\gamma} - 1\right)(\underline{k_L} - k_H)$. The reason is that the bank L the source of savings on the capital is not only δ but also the fact that the bank H gets a different insurance premium.

The second observation is that k_0 does not play any role in (14). This implies that the initial capital structure does not play any role for the bank's incentive to misreport once i is revealed to the bank. This is due to the fact that δ is independent of k_0, k_H, k_L, and x. Hence, once we maintain exogenously given δ we can simplify the model by dropping the initial stage of financing the project before i is revealed and stick to the timing proposed in the baseline model.

8.2 Uninsured deposits

Observe that the same truthtelling constraint as (14) arises when the deposits are uninsured. The reason is that the bank that finances a project of size 1 has $1-k$ deposits for which it has to pay a gross deposits rate $\frac{1}{1-p}$ to compensate the depositors for probability of default. If the depositors infer the probability of default of the bank i from the capital level after the regulatory inspection then in truthtelling equilibrium the gross deposit rate of the bank caught on misreporting is $\frac{1}{1-p_H}$. At the same time the minimum capital level that the bank i with uninsured deposits needs to monitors is $(1 - p_i)\left(1 + r - \frac{1-k_i}{1-p_i}\right) = b$or $\underline{k_i} = 1 + b - (1 - p_i)(1 + r)$, which is the same as in the case of insured deposits. This establishes the equivalence of the case between insured and uninsured deposits when the regulator provides the information about i.

9 Appendix C

We assume that the investors are not efficient users of the bank's project, i.e., they return they generate on the project in case of monitoring falls by $\lambda > 0$, and have a higher cost of monitoring as expressed by higher private benefits, $b + \beta$ and $\beta > 0$. The price they pay for the project in case they observe i is $1 + r_i - \lambda - \frac{\delta(b+\beta)}{1+\delta} = P_i^* - \lambda - \frac{\delta\beta}{1+\delta} < P_i^*$. Hence, we get that the return on the bank capital is lower because there is additional discount when the project is sold, $\lambda + \frac{\delta\beta}{1+\delta}$. This decreases the social desirability of the insensitive capital requirements. Hence, the case 1 from Lemma 3 obtains only for sufficiently low β and λ, because the capital is used more efficiently only when the discount on the price from β and λ does not offset the gain from transferring the project to the investors who monitor less intensely than the bank.

Introducing a wedge in the cost of capital between the bank and the investors also has similar consequences. If the cost of capital for the investors is more costly then the capital of the bank, the intuition behind the consequences is the same as for $\beta > 0$ and $\lambda > 0$. If the cost of capital for the investors is less costly for the bank (see Parlour and Plantin (2008), Parlour and Winton (2009)), then selling the project becomes more attractive. Its effect is similar to introducing the positive probability of default as proposed in Section 4.1.

Figures

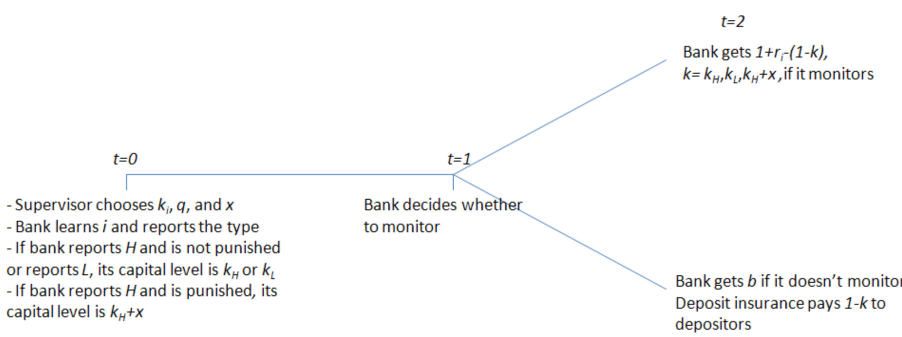

Figure 1: The timeline of the events for the regulated bank when there is no secondary market.

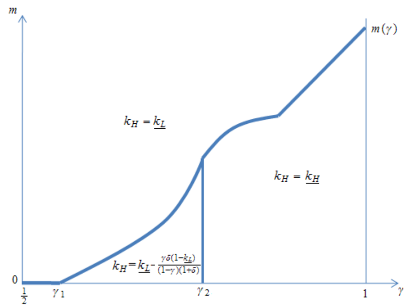

Figure 2: Proposition 1 in case $\gamma_2 > \gamma_1$. The figure illustrates the choice of socially optimal k_H as a function of inspection noise (γ) and inspection cost (m). The figure distinguishes three regions: a region defined by $m > m(\gamma)$ in which the capital requirements are insensitive ($k_H = \underline{k_L}$); a region defined by $m \leq m(\gamma)$ and $\gamma < \gamma_2$ in which the capital requirements are sensitive but complemented with leverage ratio ($k_H = \underline{k_L} - \frac{\gamma\delta(1-\underline{k_L})}{(1-\gamma)(1+\delta)}$), and a region defined by $m \leq m(\gamma)$ and $\gamma \geq \gamma_2$ in which the capital requirements are sensitive ($k_H = \underline{k_H}$).

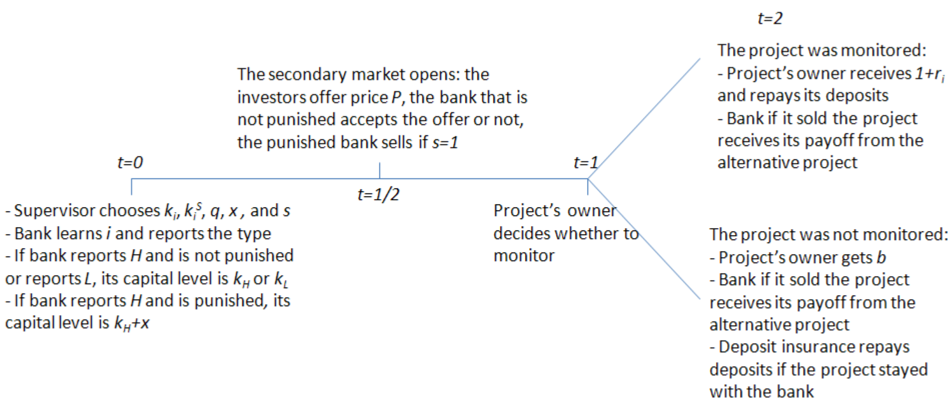

Figure 3: The timeline of the events for the regulated bank when there is secondary market.

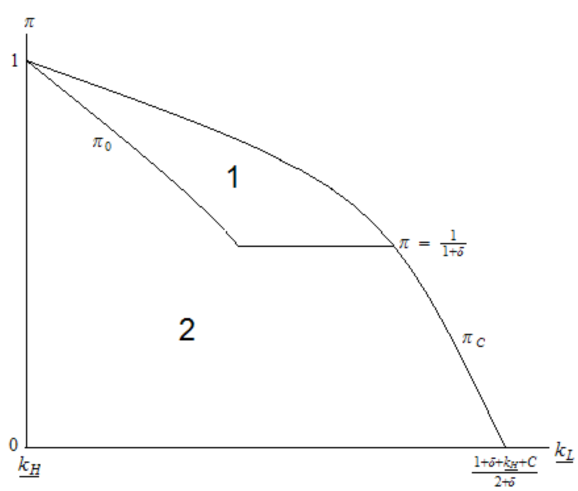

Figure 4: The figure illustrates the regions in which the respective solutions for k from Lemma 3 arise. The region 1 corresponds to the solution $k \geq k_{P2}$ (the case 1), the region 2 to the solution $k = \underline{k_L}$ (the case 2).

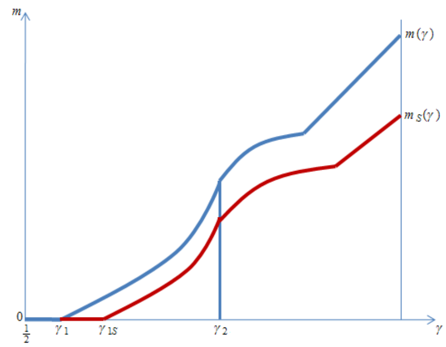

Figure 5: Comparison of solutions without and with secondary market for $\pi \in \left[\max\left\{\pi_0; \frac{1}{1+\delta}\right\}; \pi_C\right)$ and $\underline{k_L} \in \left(\underline{k_H}; \min\left\{1; \frac{1+\delta+\underline{k_H}+C}{2+\delta}\right\}\right)$. The blue (upper) curve is defined as $m = m(\gamma)$ and the red (lower) curve as $m = m_S(\gamma)$. The region between the blue and red curve is the region in which the insensitive capital requirement with secondary market and sensitive capital requirements without secondary market deliver the highest social welfare.

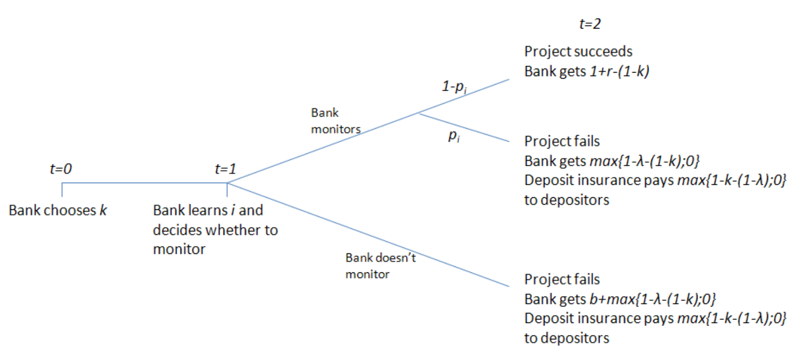

Figure 6: Modified time line