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Abstract

How do regulators 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.

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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' and regulators' 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 for these assets matters for design of capital requirements for two reasons that have opposite welfare implications. First, banks can use their capital more efficiently by selling their assets for which capital requirements are too high from their perspective.[4] Second, if capital requirements

[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." In June 2012 Barclays admitted to misreporting their Libor submissions during the recent financial crisis to look healthier in regulators' and their counterparties' eyes, effectively increasing its potential leverage (Financial Times (2012)).

[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 all other examples from footnotes 1 and 2.

[4] Bank capital requirements are a prominent motive for loan sales by banks, and for credit risk transfer in general

depend on banks' reporting, the banks' incentive to misreport is stronger when they can sell their assets than when they cannot. The reason is that misreporting banks sell their low-value asset for a price of a high-value asset, whereas if they keep it, they only lower their capital requirement. We argue that in a modern banking system, where bank assets are tradable, bank capital regulation based on banks' reporting may save on costly bank capital and lead to well-capitalized banks only if the banks with high value assets *are not allowed* to sell them. At the same time, a high and uniform capital requirement becomes more socially desirable, because banks can sell their assets to use their capital more efficiently without engaging in misreporting activities. These findings have important implications for the current overhaul of bank capital regulation.

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.[5] Only the bank knows the value of its project. Capital requirements are needed because of a moral hazard problem: Capital provides the bank with an incentive to exert costly monitoring effort (Holmstrom and Tirole (1997), 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 a penalty in the form of 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 form of penalty for misreporting and the probability of inspection.

(see e.g. Acharya et al (forthcoming), Berger and Udell (1993), Demsetz (2000), Drucker and Puri (2009), Duffie (2007), Parlour and Plantin (2008), Saunders and Cornett (2006)).

[5] 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)).

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 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 the 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 a 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 investors and redeploy its capital into new investment. The investors have two features. First, the investors cannot generate the full return on the project, limiting the social benefit of the project's sale (Acharya and Yorulmazer (2007), Parlour and Winton (2008)). Second, the investors infer the project's value from the bank's level of capital that reflects information gathered by the regulator.[6] 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 is used more efficiently when the bank sells the project and redeploys its 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

[6] First, banks keep substantial amount of loans and other assets for some time on their balance sheets (as available-for-sale and trading assets) before they sell them. Second, the model generalizes to the case in which the bank has several projects and the investors observe only the aggregate capital level. Finally, the idea that the supervisory bank exams produce information that is new and relevant for the bank's investors has been well documented empirically. The most prominent example is the success of stress tests conducted by the Federal Reserve in 2009 in providing crucial information about banks to the market (Perstiani, Morgan and Savino (2010)). Other papers include Berger and Davies (1998), Flannery and Houston (1999), Berger, Davies and Flannery (2000), DeYoung et al. (2001), and Gunther and Moore (2003).

possibility of selling the project as a high-value bank.

First, we show that a necessary condition for sensitive capital requirements to be socially efficient is to eliminate the high-value bank's incentive to sell its project. The social benefit of selling the project is low under sensitive capital requirements because such capital requirements already reduce 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 only lower its capital requirement. The result is that sensitive capital requirements become socially inefficient because the cost of additional inspection and penalty to counteract the increased benefit of misreporting is higher than the social benefit of redeploying capital. Hence, the necessary condition for sensitive capital requirements to be socially efficient is to discourage the high-value bank from selling its project. Because the regulator finds it optimal to discourage selling, the optimal sensitive capital requirements are the same as in the case without the secondary market.

Second, we show that the insensitive capital requirements can become more socially desirable when a secondary market exist. They become so when the social cost of selling the project to investors is low. The social benefit of selling due to more efficient use of bank capital is counteracted by the fact that investors buying the project cannot generate the full return on it, which lowers the amounts of redeployed capital and of the new investment. Hence, the project's sale becomes more efficient than keeping the project in the bank when cost of transfer to investors is sufficiently low. In such a case, insensitive capital requirements become more socially desirable relative to sensitive 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 and well-capitalized banks using sensitive capital requirements will backfire and result in lack of transparency and under-capitalized banks when there are no restrictions on banks' asset sales. This may occur especially when risk-based capital requirements, such as those from Basel II or SEC's net capital rule, are combined with measures such as the Basel III leverage ratio or standardized haircuts. Measures such as leverage ratio that are insensitive to risk "punish" banks with safe and high-quality assets and induce them to sell such assets. In response, banks with riskier and low-quality assets might increase their efforts to misreport their quality and become undercapitalized, undermining the goal of sensitive capital requirements to provide transparency and sufficient bank capitalization. Eventually adverse selection might lead to a breakdown of the secondary markets and undercapitalized banks not being able to sell their assets.

The paper offers three policy implications for achieving the regulatory goal of saving on costly bank capital while maintaining well-capitalized banks. First, the necessary condition to achieve this objective under sensitive capital requirements is to discourage banks with high-quality assets to sell them.[7] It will also eliminate the above mentioned unintended consequence of a leverage ratio and bring back its original purpose, which is to eliminate the misreporting incentive.

Second, in the contemporary banking system, where many bank assets are tradable, a high capital requirement uniform across all banks might be more effective than capital requirements based on banks' reporting, if the social cost of transferring assets outside of the banking system is sufficiently low. Although not modelled here explicitly, the key to holding these social costs low is elimination of regulatory arbitrage in bank capital regulation due to tradability of assets (Acharya et al. (forthcoming)).[8]

Third, 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).

With respect to policy implications our paper is related to two proposals for regulatory reforms. Haldane and Madouros (2012) call for simple capital regulation arguing that complexity of capital regulation such as the Basel II risk-based capital requirements (that are a part of the Basel III

[7] This could be achieved by properly calibrating measures such as risk-retention rule proposed in the Dodd-Frank Act.

[8] Social cost of tradability of bank assets might increase due to regulatory arbitrage. Acharya et al. (forthcoming) show that the banks preferred to hold on to their asset-backed securities via special purpose vehicles rather than sell them to investors due to the capital relief related to keeping assets off balance sheet. This might contributed to their undercapitalization, once they took these assets back to their balance sheets at the start of the financial crisis in 2007.

Accord) is a source of banks' opacity and of incentives for gaming capital regulation. In a narrow sense, our paper can be viewed as theoretical underpinnings of their argument. However, our paper also makes a more subtle point: even if opacity due to complexity of regulation is low (as proxied by low noise of regulatory inspection) banks' incentives to misreport their riskiness are still high when the market relies on banks' information supplied for regulatory purposes. Hence, in modern banking systems risk-based capital regulation might result in undercapitalized and intransparent banks at the same time. The main policy implication of our paper effectively calls for simple capital regulation whose *only* objective is a well-capitalized banking system even at the cost of suppressing valuable information about individual banks. In that sense, this policy implication is similar to a proposal from the Wheatley Review on LIBOR (Her Majesty Treasury (2012)) according to which credibility of LIBOR as a benchmark for the cost of unsecured interbank borrowing could be greatly enhanced if publication of banks' individual submissions were postponed for 3 months. That way submitting banks would have lower incentives to misreport their subsmissions because submissions could not be used by the market as a signal of banks' current riskiness.

The theoretical 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 banks' 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.[9] 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 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

[9] Parlour and Plantin (2008) describe the negative consequence of secondary markets on bank's incentive to exert monitoring effort. We abstract from that possibility as it is present both under sensitive and insensitive capital requirements and want to concentrate on selling being detrimental to truthful reporting.

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 Appendices contain 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 3.1).

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 deposit insurance agency and supplied at an interest rate normalized to 0.[10] 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.[11]

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

[10] The case of uninsured deposits is discussed in Section 4.1 and the case of outside shareholders in Section 4.2.

[11] 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.

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.[12] (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 à 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 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

[12] $\delta > r_i$ (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 sufficiently high k. The additional cases do not provide new insights because the misreporting incentive would still exist.

matter for the bank's subsequent decisions.[13] 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-operator 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, $1 + r_i - (1 - k)$. $k\left(1 + \delta\right)$ 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, making banking socially inefficient.[14]

Insured depositors' indifference toward the bank's monitoring decision provides a need for bank regulation (Section 4.1 shows that there is still scope for regulation if deposits are *un*insured). The power to regulate the bank belongs to a regulator who 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.[15] We refer to the level of capital required by the regulator as capital requirements. The regulator also has the power to impose deposit insurance fees on the bank. The

[13] 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 incentive to misreport still is present constant $\delta > 0$ is sufficient for our purpose. Hence, we can assume that the bank learns i before it chooses k.

[14] Social welfare is then $b - 1 < 0$ due to (2), where b is the unregulated bank's profit and 1 are deposits to be repaid.

[15] In this simplified setup, the supervisor would observe at $t = 2$ whether the bank monitored the project. However, we assume that the supervisor 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.

fee will be 0 for the bank that monitors its project, because the monitoring bank does not default in the baseline model. In Appendix B we generalize our framework to stochastic returns where deposit insurance fees for banks monitoring the project are positive.

The bank i monitors at $t = 1$ when its payoff from monitoring is not lower than b:

$$1 + r_i - (1 - k) = r_i + k \geq b. \tag{4}$$

Monitoring is more attractive when the project's net return r_i and the level of capital k increase. Solving (4) 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 banking being socially inefficient due to lack of monitoring. 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, $1 + r_i - (1 - k) - k\,(1 + \delta) = r_i - k\delta$, and is positive for any $k \geq \underline{k_i}$ due to (1) and (2). 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.[16]

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 $\underline{k_H} < \underline{k_L}$.[17] To simplify the exposition of the results, we assume that

$$\pi < \frac{(1 + \delta)\left(1 - \underline{k_L}\right)}{(1 + \delta)\left(1 - \underline{k_L}\right) + \delta(r_H - r_L)}. \tag{5}$$

[16] 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).

[17] 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 $\underline{k_L}$, $r_L - \delta\underline{k_L}$: $b - (1 + \delta)\,\underline{k_H} = r_H - \delta\underline{k_H} > r_L - \delta\underline{k_L} = b - (1 + \delta)\,\underline{k_L}$.

(5) 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. This occurs despite the fact that such a capital requirement $\underline{k_L}$ imposes a burden on the bank H that has to hold more capital than $\underline{k_H}$. Under (5) the probability that $i = L$ is so high that the regulator prefers to impose a burden on the bank H than to tolerate the bank L's lack of monitoring and default for an insensitive capital requirement lower than $\underline{k_L}$.[18] (5) 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.[19] 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.[20] 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.[21]

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,

[18] Social welfare under $\underline{k_L}$ 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 under $\underline{k_H}$ is the bank's expected return if it monitors the project H and defaults on the project L: $\pi(r_H - \delta\underline{k_H} - (1+\delta)(1-\pi)(1-\underline{k_H})) + (1-\pi)(b - (1+\delta)\underline{k_H} - (1+\delta)(1-\pi)(1-\underline{k_H}))$, where the regulator imposes a fair deposit insurance premium $(1-\pi)(1-\underline{k_H})$ on each bank i. The premium arises because with probability $1-\pi$ the bank is L. Such a bank does not monitor under $\underline{k_H}$ and defaults. 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 and cancel out. Comparing both expressions for social welfare delivers (5).

[19] 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.

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

[21] 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.

the regulator can use only recapitalization as a 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.[22] 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.[23]

Formally, the regulator solves the following problem:

$$\max_{k_H, k_L, q, x} \pi(r_H - \delta k_H - q(1-\gamma)\delta x) + (1-\pi)(r_L - \delta k_L) - \pi q m. \tag{6}$$

subject to

$$k_H \geq \underline{k_H}, k_L \geq \underline{k_L}, \tag{7}$$

$$r_L - \delta k_L \geq (1 - q\gamma) \left[\max\left[b; r_L + k_H\right] - k_H(1+\delta)\right] + q\gamma \left[\max\left[b; r_L + (k_H + x)\right] - (1+\delta)(k_H + x)\right], \tag{8}$$

$$r_H - \delta k_H - q(1-\gamma)\delta x \geq r_H - \delta k_L, \tag{9}$$

$$x \leq 1 - k_H, \tag{10}$$

$$q \in [0; 1]. \tag{11}$$

The regulator chooses k_H, k_L, q, and x to maximize social welfare (6) subject to constraints (7)-(11). Social welfare (6) 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 (5). The first term in (6) is

[22] The case when the regulator cannot commit to the supervisory scheme is discussed in Section 4.3.

[23] 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 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 (6) 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.

(7) ensures that each bank i has enough capital to monitor its project after revealing its type truthfully. (8) 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 (8) 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. (9) guarantees that the bank H reports its type truthfully. The left-hand side of (9) 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 $k_L \geq \underline{k_L} > \underline{k_H}$. (10) is the upper bound on x because recapitalization can lead maximally to 100% capital financing. In a more general setup x, would be bound by a participation constraint, which would not affect the results but it would complicate the algebra. The bank's participation constraints are ignored because they are implied by (1), (2), (8), and (9).

The solution to the regulator's problem delivers the following proposition.[24]

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 (8)-(11) such that social welfare is maximized if* $k_L = \underline{k_L}$ *and:*

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

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

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 trade-off. 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 $\underline{k_H}$ (see Blum (2008) for a similar result). 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 percent 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 $\underline{k_H}$. Such k_H shares a feature of the Basel III leverage ratio that imposes a lower bound on capital ratio for all banks independent of their riskiness: the bank H has to finance with more capital than would be sufficient for it to behave prudently.

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 any asset-backed security such as 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 have funds to buy the project from the bank but cannot originate it. The investors can pay maximally only a fraction of the project i's return $1 + r_i$. This assumption can be justified in several ways: The investors are not the most efficient users of the project (Acharya and Yorulmazer (2007)), they have to perform costly monitoring to receive the full project's return (Parlour and Winton (2008)), or they have a positive net opportunity cost of investing in the project (Appendix C explores these explanations as micro-foundations for this assumption). Because none of these explanations is crucial for the results, we assume that the project's value for the investors equals the expected project's return diminished by an exogenous discount λ. λ is then a social cost of selling the project to the investors, because the bank cannot generate the full return on the project from its sale and, therefore, the amount of investment in the alternative project is diminished by λ.

We assume that

$$\lambda > \frac{\delta b}{1+\delta}. \tag{12}$$

(12) guarantees that there is a threshold $\widehat{k_i} > \underline{k_i}$ such that the bank i wants to sell the project for any $k_i \geq \widehat{k_i}$ and keep it for any $k_i < \widehat{k_i}$ (we assume the bank sells if it is indifferent between selling and keeping the project). If (12) does not hold, the model is not interesting and unrealistic, because

[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)).

the regulator would always want the bank to sell the project, i.e., monitoring of the project by the bank would be less socially desirable than selling the project to investors ((12) can be derived using (15) for $k_i^S = 1$). (12) also implies that the regulator will always introduce $k_i \geq \underline{k_i}$, because otherwise the bank i would prefer to keep and not monitor the project.

Finally, the investors do not have technology to obtain information about i on their own before they purchase the project. However, they observe the bank's capital and try to infer i from it before they purchase the project. Two remarks are in order. First, there is empirical evidence that changes in bank capital after supervisory exams provide new information to the investors, as shown recently by Peristiani et al. (2010) in the context of stress tests conducted by the Federal Reserve in 2009 (other examples are provided by Berger and Davies (1998), Flannery and Houston (1999), Berger, Davies and Flannery (2000), DeYoung et al. (2001), and Gunther and Moore (2003)). Second, although such an assumption suggests the unrealistic case where the investors observe capital requirements for bank's individual projects, we show in Appendix D that the results of our model generalize to a more realistic setup with banks having a portfolio of projects H and L. In such a case, the *aggregate* capital level is still sufficient for the investors to infer the quality of projects the bank intends to sell.

3.2 Optimal capital requirements

We assume that the regulator is also able to set capital requirements k_i^S for the bank i that sells its project. In order to save on notation unnecessary for our main results, the punished bank H also is subject to k_H^S. Although the regulator could also punish the bank with selling combined with restrictions on payouts of the proceeds (as is often in case of undercapitalized banks), for the time being, we assume that such a penalty is not socially optimal. At the end of the section, we provide conditions under which this is the case and show that this assumption is not crucial for the main results.

The timing from Section 2 is modified as follows and is summarized in Figure 3. At $t = 0$ the regulator chooses and commits to the capital requirements k_H, k_L, k_H^S, and k_L^S, the probability of inspection q upon report of H, and penalty x. 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 secondary market opens. 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. At $t = 1$ the bank that kept the project decides whether to monitor. At $t = 2$ the returns are realized.

We do not analyze explicitly the possibility that the bank could sell its project between learning and reporting i if $q > 0$ for two reasons. First, although banks sometimes sell loans before formally assigning a capital charge (i.e., before reporting i in the model), a substantial portion of assets including loans that the banks intend to sell is still reported and kept on the balance sheets (as available-for-sale and trading assets) for some time before selling. Hence, the banks need to assign capital charges to these assets (i.e., report their types in the model). Second, in our setup selling before reporting is not optimal, because the bank H prefers to sell after reporting given that the investors can infer the true i from bank's capital under sensitive capital requirements. Hence, the bank L that intends to mimic the bank H does not gain anything from selling before reporting. Finally, for insensitive capital requirements the timing of selling does not matter, because there is no reporting.

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 inspects the bank $(q > 0)$ and does not inspect 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 with inspection

We now derive 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 bank's incentive to sell its project 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 it can only be the bank H in a truthtelling equilibrium. Hence, the competitive investors offer $P_i^* = 1 + r_i - \lambda$ for the project of the bank with k_i or P_H^* for the project of the bank with $k_H + x$.

If the bank i that is not punished at $t = 0$ sells, its payoff at $t = \frac{1}{2}$ is:

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

$P_i^* - \left(k_i^S - k_i\right)$ is the investment in the alternative project yielding $1+\delta$ per invested unit after the bank's project is sold for P_i^* and the additional capital $k_i^S - k_i$ is injected into the bank according to k_i^S. $1 - k_i$ is the payout to the depositors. Because the bank has to repay deposits $1 - k_i$ after selling the project, $k_i^S - k_i$ has to be high enough to cover $1 - k_i$, i.e., $k_i^S \geq 1$. The opportunity cost of investing capital k_i in the bank does not enter the bank's payoff at $t = \frac{1}{2}$ because it is sunk at $t = 0$. If the bank i does not sell at $t = \frac{1}{2}$, its payoff is

$$1 + r_i - (1 - k_i) = r_i + k_i. \tag{14}$$

The bank i sells if (13) is not lower than (14). Solving this inequality for k_i and using expressions for P_i^* and $\underline{k_i}$ delivers that the bank i sells if the capital requirement k_i for keeping the project is sufficiently high

$$k_i \geq \underline{k_i} + \left(k_i^S - 1\right) + \frac{1+\delta}{\delta}\left(\lambda - \frac{\delta b}{1+\delta}\right). \tag{15}$$

The bank i sells only if capital k_i invested at $t = 0$ and redeployed at $t = \frac{1}{2}$ is so high that return on redeployed capital k_i compensates for the loss of return from selling the project at the discount λ and from retaining additional capital at the bank in accordance with k_i^S. The bank sells for sufficiently high k_i because by selling the project at $t = \frac{1}{2}$ the bank can redeploy its initial capital k_i to a more productive use. The gross return on redeploying one unit of capital at $t = \frac{1}{2}$ to the alternative project is $1 + \delta$ instead of 1 when the bank keeps the project until $t = 1$. Similarly, the punished bank H is more willing to sell than the unpunished bank H for a given k_H, because it has to invest even more capital, $k_H + x$, into the project at $t = 0$. Hence, the punished bank H sells if

$$k_H \geq \underline{k_H} + \left(k_H^S - 1\right) + \frac{1+\delta}{\delta}\left(\lambda - \frac{\delta b}{1+\delta}\right) - x. \tag{16}$$

(16) arises after comparing the punished bank H's payoff from selling,

$$\left[P_H^* - \left(k_H^S - (k_H + x)\right)\right](1+\delta) + \left(k_H^S - (k_H + x)\right) - (1 - (k_H + x)), \tag{17}$$

and its payoff from keeping, $1 + r_H - (1 - k - x) = r_H + k_H + x$. The last two expressions are analog to (13) and (14) after taking into account recapitalization with x.

Selling allows the bank i to reduce the burden from high capital requirements by redeploying its capital to a more productive use. Selling is especially attractive for the bank H, because the regulator might want to subject this bank to a capital requirement k_H that is higher than $\underline{k_H}$ (such as leverage ratio). Such a capital requirement might be needed when the probability of detection of true i by the regulator, γ, is low, as in Section 2.

Although the possibility of selling the project at $t = \frac{1}{2}$ allows the bank to reduce the burden from high capital requirements, it also diminishes the bank L's incentive to report its type truthfully at $t = 0$. Here we present intuition behind this result and the proof of Proposition 2 that follows contains the formal argument. First, if k_i, k_i^S, and x are such that each bank i keeps the project at $t = \frac{1}{2}$ (expression (16) is violated for each i), the misreporting incentive and constraints guaranteeing truthtelling are the same as in the case without the secondary market, (8) and (9).

Second, once k_i, k_i^S, and x are such that at least the punished bank H sells its project (at least

(16) for $i = H$ is satisfied), the truthtelling constraint for the bank L becomes tighter than (8) or might even fail to hold. The main reason for tightening or even breakdown of this constraint is that the bank L's payoff from misreporting is higher than in the case where the bank H does not sell. When the bank H sells, the misreporting bank L can sell its low-value project for the price of the high-value one, because the investors pay such a price for a project sold by a bank with capital level of k_H or $k_H + x$. If the bank H does not sell, the misreporting bank L keeps its low-value project instead of selling it for the price of the project H and only lowers its capital requirement from k_L to k_H.

The truthtelling constraint for the bank L will fail to hold, when the regulator ignores the bank H's incentive to sell when deriving optimal sensitive capital requirements (we show it formally in the proof of Proposition 2). Let's assume that k_H is such that the bank H sells. When the regulator ignores the bank H's selling and sets no restrictions on payouts to shareholders beyond obligatory deposit repayment ($k_H^S = 1$), the bank L misreports and truthtelling unravels for any q and x. The reason is that by selling the project both unpunished and punished bank H can avoid the burden from increased k_H and recapitalization penalty. Then, the same applies to the misreporting bank L. Hence, the bank L's expected return from misreporting will be higher than the return from reporting its true type for any q and x, because it avoids penalty and its misreporting return will be the same as the bank H's return, whose project is more valuable than the project L. This unraveling of truthtelling may lead to banks keeping their projects and, in turn, to undercapitalization and default of the misreporting bank L. The reason is that for sufficiently low k_H the bank L might be willing to keep the project rather than sell it, resulting in its undercapitalization and default.

Even if the regulator restricts payouts after the project's sale so that truthtelling does not unravel (for some $k_H^S > 1$), obtaining the bank L's truthtelling becomes costlier for the regulator if the bank H still prefers to sell than when it does not sell. The reason is again the same: the bank L's higher payoff from misreporting due to bank H's selling. The regulator has to inspect the bank L more often and impose a harsher penalty to counteract the increased incentive to misreport than in the case when the bank H does not sell.

The negative consequence of ignoring the bank H's incentive to sell is especially important if the regulator implements k_H higher than $\underline{k_H}$ with a purpose of eliminating the bank L's misreporting as in Section 2 (such as the Basel III leverage ratio). As seen above, such k_H may actually undermine the regulator's efforts to eliminate misreporting, because this elevated k_H may prompt the bank H to sell the project to reduce the burden from such k_H and increase the bank L's incentive to misreport.

Once the regulator takes into account the negative effect of the bank H's selling incentive on the bank L's incentive to report its true type, we can prove the most important result of the paper.

Proposition 2 *Suppose there is a secondary market for the bank's project and $q > 0$. The regulator finds it optimal to provide the bank H with an incentive to keep the project. The regulator does so by imposing any k_H^S such that (16) does not hold for k_H and x that are to be implemented.*

Proof. See Appendix A. ■

Proposition 2 shows that when the regulator implements sensitive capital requirements with the presence of the secondary market, it is socially efficient to make the bank H keep the project. This reduces the bank L's incentive to misreport and lowers the social cost of inspection and penalty incurred when implementing the sensitive capital requirements. Making the bank H keep the project is socially beneficial despite of the benefit from selling, i.e., the reduction of the burden from capital requirements. This benefit from selling is not sufficiently high to make the project's sales socially efficient under sensitive capital requirements. The reason is that sensitive capital requirements already reduce the bank H's burden from keeping the project by allowing for $k_H < \underline{k_L}$. Hence, the amount of capital redeployed to the alternative project by the bank H is too small to compensate for the social cost of the bank L's increased incentive to misreport.

If we relaxed (12) sufficiently, the social benefit of selling could be higher than its cost from increasing the incentive to misreport. But as discussed earlier, relaxing (12) would make the model uninteresting and unrealistic.

The immediate consequence of Proposition 2 is that any k_H higher than $\underline{k_H}$ (such as leverage ratio) can be introduced to fulfill its original purpose of diminishing the bank L's incentive to misreport for low probability of detection of true i, γ, as in Section 2. The reason is that the bank H keeps its project for any k_H, so that the bank L's misreporting incentive does not increase.

In the context of our setup, the regulator can eliminate the bank H's incentive to sell by making the bank H retain a sufficiently high amount of proceeds from selling. To do so, the regulator sets sufficiently high k_H^S. Such high k_H^S discourages the project's sale, because it reduces the amount of capital that can be redeployed to the alternative project. Alternatively, the regulator could simply tell the bank H to not sell the project, because the project's sale is observable. We disregard this alternative in order to keep the amount of regulatory tools at its minimum. The capital requirements k_H and k_H^S allow us to achieve this goal, because they can be used not only to change the bank's selling incentive (as shown here and in the next section), but also to guarantee that a selling bank has enough proceeds to repay depositors (as in the next section).

After the regulator makes selling unprofitable for the bank H by making it retain enough capital, selling *combined* with prohibition of paying out any proceeds from a sale to the shareholders could be used as a penalty for misreporting. The reason is that the project is sold at a discount λ to its value. However, as the next Lemma shows that necessary (but not sufficient) condition for optimality of such a penalty is sufficiently high λ. The reason is similar to the one driving Proposition 2. The punished bank L sells its low-value project as the high-value one, because the investors pay P_H^* for a project of the bank with capital level $k_H + x$ in the truthtelling equilibrium. Hence, λ has to be high enough to compensate for this increased incentive to misreport.

Lemma 1 *Suppose there is a secondary market for the bank's project and $q > 0$. If $\lambda > r_H - r_L$, selling with prohibition of payouts could be used as a penalty. If $\lambda \leq r_H - r_L$, selling with prohibition of payouts is not socially optimal as penalty, and the optimal sensitive capital requirements k_H and k_L are the same as in Proposition 1.*

Proof. See Appendix A. ■

In what follows, we assume that $\lambda \leq r_H - r_L$ and $r_H - r_L > \frac{\delta b}{1+\delta}$ (due to (12)). Hence, Proposition 2 and Lemma 1 imply 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. Although $\lambda > r_H - r_L$ would give the regulator more room to punish the bank L, it complicates the derivation of optimal sensitive capital requirements by adding more cases, while the main result of the paper, Proposition 2, is unaffected.

3.2.2 The case without inspection

We now derive the optimal choice of capital requirements when the regulator does not inspect. We start again with the secondary market at $t = \frac{1}{2}$. We present the solution for insensitive capital requirements, $k = k_H = k_L$ and $k^S = k^S_H = k^S_L$. As we show in the proof of Lemma 3, 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 set k_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 that are insensitive.[26] Hence, we have a classic case of adverse selection (Akerlof (1970)). The price offered by the investors depends on each bank i's incentive to sell the project, and vice versa. If the bank i sells the project, its payoff is analog to expression (13) (we drop the index i given that there is one price and insensitive capital requirements)

$$(P + k)(1 + \delta) - 1 - k^S \delta. \tag{18}$$

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,

$$\max[b; r_i + k]. \tag{19}$$

The bank i sells if (18) is not lower than (19). Solving this inequality for P delivers that the bank i sells if P is high enough:

$$P \geq \frac{1 + k^S \delta + \max[b; r_i + k]}{1 + \delta} - k. \tag{20}$$

The right-hand side of this inequality is the bank i's reservation price. The reservation price decreases in k, because again at $t = \frac{1}{2}$ one unit of capital yields $1 + \delta$ if invested in the alternative

[26] Bank's signaling with capital is not possible because its cost is the same for each bank i. Even if signaling 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 mimic the bank H and default.

project rather than at most 1 when the bank keeps the project (0 if the bank does not monitor). Hence, the bank i's willingness to sell the project increases again with k (for a given P). Moreover, the bank H is less willing to sell than the bank L for given k and P, because the project H is more valuable than L.[27]

As the following Lemma shows, depending on k one of the following three outcomes can arise on the secondary market: (i) each bank i sells for a price reflecting adverse selection, $1 + \pi r_H + (1-\pi) r_L - \lambda$, (ii) only the bank L sells for the price, $1 + r_L - \lambda$, or (iii) none of the banks sells.

Lemma 2 *Suppose there is a secondary market for the bank's project and $q = 0$, $k = k_H = k_L$, $k^S = k_H^S = k_L^S$. Then there exist such thresholds for k as functions of k^S, $k_1\left(k^S\right)$ and $k_2\left(k^S\right)$, that one of three cases may arise:*

1. *For $k \geq k_1\left(k^S\right)$ each bank i sells the project for a price $1 + \pi r_H + (1-\pi) r_L - \lambda$.*
2. *For $k \in \left[k_1\left(k^S\right); k_2\left(k^S\right)\right)$ and $\pi < \min\left[\frac{1}{1+\delta}; \pi_0\right]$ only the bank L sells the project for a price $1 + r_L - \lambda$.*
3. *For $k < \min\left[k_1\left(k^S\right); k_2\left(k^S\right)\right]$ none of the banks sells the project.*

Proof. See Appendix A. ■

If k is sufficiently high (the case 1), even the bank H sells the project. The return from investing capital k in the alternative project is so high that it compensates the bank H for selling its project at the discount λ and the adverse selection discount. If k is intermediate (the case 2), only the bank L sells its project. For some low k even the bank L keeps the project (the case 3), because return on such a small k from the alternative project does not compensate for selling the project at the discount λ.[28]

Once the regulator knows which outcome on the secondary market arises for a given k and k^S, the regulator chooses the outcome that delivers the highest welfare and corresponding capital requirements.

[27] The bank H's reservation price is not lower than the one of the bank L for given k and k^S: $\left(\frac{1+k^S\delta+\max[b;r_H+k]}{1+\delta} - k\right) - \left(\frac{1+k^S\delta+\max[b;r_L+k]}{1+\delta} - k\right) = \frac{\max[b;r_H+k]-\max[b;r_L+k]}{1+\delta} \geq 0$ because $r_H > r_L$.

[28] 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 equilibrium from the case 1 in 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.

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 *and* k^S *such that the following conditions are fulfilled. The optimal* k^S *is* 1.

1. *For* $\lambda \in \left[\frac{\delta b}{1+\delta}; \frac{\delta[b+\pi(r_H - r_L)]}{1+\delta}\right)$ *the highest social welfare id obtained when each bank* i *sells its project. Social welfare is higher than in case of the insensitive capital requirement* $\underline{k_L}$ *without the secondary market. The regulator can implement such an outcome by imposing any* $k \geq \underline{k_H} + \frac{1+\delta}{\delta}\left[\left(\lambda - \frac{\delta b}{1+\delta}\right) + (1-\pi)(r_H - r_L)\right]$.
2. *For* $\lambda \geq \frac{\delta[b+\pi(r_H - r_L)]}{1+\delta}$ *the highest social welfare is obtained when each bank* i *keeps its project. Social welfare is the same as in the case of the insensitive capital requirement* $\underline{k_L}$ *without the secondary market. The optimal* k *is* $\underline{k_L}$.

Proof. See Appendix A. ■

The results in Lemma 3 highlight the following trade-off that the regulator faces under insensitive capital requirements. On the one hand, selling allows the bank to reduce the burden from capital requirements, and therefore their social cost, because the bank capital is used more efficiently after being redeployed into the alternative project. This is important for the bank H that carries the burden of the insensitive capital requirements. On the other hand, the project is sold at a discount λ that results in social cost of transferring the project to outside investors, because λ lowers the project's price and therefore the amount of capital redeployed into the alternative project. Hence, it is more efficient to sell the project and save on the bank's costly capital when λ is sufficiently low (the case 1). If λ is too high (the case 2), it is more efficient to impose the lowest possible capital requirement for which both banks keep and monitor the project, $k = \underline{k_L}$.[29] The regulator can implement the desirable outcome on the secondary market by setting such k for $k^S = 1$ that the banks either sell or keep the project.

The consequence of Lemma 3 is that for sufficiently low λ (the case 1) the insensitive capital requirements, i.e., the case in which the banks are not required to reveal their true i, become more

[29] The other case where the bank L sells and the bank H keeps the project is not socially optimal. The reason is that the regulator cannot set lower k than $\underline{k_L}$, because otherwise the bank L would always prefer to mimic the bank H.

socially desirable when there is a secondary market than when it does not exist. The reason is that the secondary market allows the bank H's to reduce the burden from the insensitive capital requirement $\underline{k_L}$. It is important to note that selling is optimal only when its *social* cost is low. As shown by Acharya et al. (forthcoming) the ability to sell assets allowed banks to use securitization and shadow banking activities to exploit regulatory arbitrage opportunities in capital regulation that might have contributed to banks' undercapitalization and, ultimately, to the recent financial crisis. Although we do not model regulatory arbitrage opportunities due to selling explicitly (they could be introduced as a wedge in the private and social cost of selling), in our model the regulator would allow only for selling if it was socially desirable.

3.2.3 The Choice of Optimal Capital Requirements

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

Proposition 3 *Suppose there is a secondary market for the bank's project and $\lambda \leq r_H - r_L$. The optimal k_H^S is such that the bank H does not sell if $k_H < k_L$. For $\lambda \geq \frac{\delta[b+\pi(r_H-r_L)]}{1+\delta}$ the solution for k_H, k_L, q, and x is the same as in Proposition 1. For $\lambda \in \left[\frac{\delta b}{1+\delta}; \frac{\delta[b+\pi(r_H-r_L)]}{1+\delta}\right)$ 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 (8)-(11) such that social welfare is maximized if $k_L = \underline{k_L}$ and:*

1. $k_H = k_L \geq \underline{k_H} + \frac{1+\delta}{\delta}\left[\left(\lambda - \frac{\delta b}{1+\delta}\right) + (1-\pi)(r_H - r_L)\right]$ *for* $m > m_S(\gamma)$;
2. $k_H = \underline{k_L} - \frac{\gamma\delta(1-\underline{k_L})}{(1-\gamma)(1+\delta)} > \underline{k_H}$ *for* $m \in (0; m_S(\gamma))$, $\gamma \in [\gamma_{1S}; \gamma_2)$ *and* $\underline{k_L} > \underline{k_L}'$;
3. $k_H = \underline{k_H}$ *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 $\gamma > \gamma_1$.

Proof. See Appendix A. ■

Proposition 3 is an immediate consequence of Lemmas 1 and 3. For $\lambda \geq \frac{\delta[b+\pi(r_H-r_L)]}{1+\delta}$ the optimal choice of capital requirements is the same as in Proposition 1, because the regulator finds it socially optimal for the bank H to keep the project for any capital requirements. For $\lambda \in \left[\frac{\delta b}{1+\delta}; \frac{\delta[b+\pi(r_H - r_L)]}{1+\delta}\right)$ the insensitive capital requirements become more socially desirable with respect to the sensitive capital requirements. The reason is that it is socially efficient for the bank H to redeploy its capital into the alternative project under the insensitive capital requirements but not 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 $\gamma > \gamma_1$ and shown in Figure 4.

4 Discussion and Policy Implications

4.1 Case of uninsured depositors

After having assumed throughout the paper 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 its project (e.g. Holmstrom and Tirole (1997)). Although uninsured deposits are a source of market discipline, regulatory intervention can still be welfare-improving if we maintain two assumptions from the baseline model: (i) uninsured depositors like the investors rely on the regulator for providing them with information on i, and (ii) the capital is a more expensive source of financing than uninsured deposits. These two assumptions are quite realistic, especially when uninsured depositors can be interpreted as institutional investors with a short-term investment horizon and a high preference for liquidity, such as money market mutual funds, corporate treasurers, or even other banks and hedge funds. Both assumptions then imply the same social benefits of sensitive capital requirements as in the baseline model: saving on costly bank capital because uninformed and uninsured depositors would require high and insensitive capital outlay from both banks. Appendix E shows the equivalence of the case of insured and uninsured deposits in a framework with stochastic returns.

4.2 Additional agency problems

We have assumed that the bank's shareholders manage the bank and are the sole suppliers of capital (so-called inside equity). Here we discuss consequences of relaxing this assumption. First, if we allow for outside shareholders, the bank L's incentive to misreport is higher than under inside equity (but still lower than when the banks can sell its project). 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 true type was revealed.[30] This would tighten the truthtelling constraint of the bank L in comparison with the case of inside equity 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 report the true type as the effect of the project's sale described in the paper. The reason is that the bank L still keeps the project on its books after the issuance of outside equity.

Second, the assumption that shareholders manage the bank assumes away a conflict of interests between the bank's shareholders and the bank's 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 regulating the compensation of bank managers).

[30] Once the new shareholders acquire the bank's shares, their own and old shareholders' interests are the same implying that capital requirements are unaffected by a distribution of 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 has the same incentive to monitor regardless of its stake in the bank.

4.3 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 due to so-called regulatory forbearance. In our model, regulatory forbearance would mean that the regulator has no incentive to conduct costly inspection and to 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 without monitoring the project. 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.

4.4 Policy implications

The first policy implication is that in a banking system in which tradability of bank assets plays a significant role, the regulator should discourage banks with high-quality assets from selling them under sensitive capital requirements. The regulator could do it by setting sufficiently high capital requirements for selling banks. In an extended framework with a divisible project, a risk-retention rule for tradable securities such as the one in the Dodd-Frank Act would serve as an equivalent instrument. Such restrictions for selling banks would help avoid potential unintended consequence of the Basel III leverage ratio, such as lack of transparency, breakdown of secondary markets, and undercapitalization of banks as described in Section 3.2.1.

Second, insensitive capital requirements can be a better tool for ensuring adequate bank capitalization than sensitive capital requirements, especially when bank assets are tradable. Banks with high-quality assets can reduce their burden from such a high capital requirement by selling their assets on the secondary market without need to report their asset quality. One important condition for insensitive capital requirements to be an effective tool is elimination of regulatory arbitrage opportunities arising from tradability of bank assets (such as lower capital requirements in trading books for the same exposures as in banking books or for exposures kept off-balance-sheet as documented in Acharya et al. (forthcoming)).

Finally, the paper suggests that the sensitivity of capital requirements might depend on the tradability of bank assets: with sensitive capital requirements for assets that are not easily sold (such as small business loans) 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 to the value of the bank's project when this value is 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. Under sensitive capital requirements the regulator finds optimal to eliminate the high-quality bank's incentive to sell its project. The reason is that the low-quality bank's incentive to misreport is greater when the high-quality bank sells rather than keeps its project.

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 banks' private information when safer or high-quality banks can sell their assets. We propose tools to reduce the incentive of these banks to sell their assets under capital requirements based on banks' reporting, and provide conditions under which a high and uniform capital requirement for all banks becomes more socially desirable when bank assets are tradable.

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Appendix A - Proofs

Proof of Proposition 1

The maximization problem (6)-(11) 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 $x < \underline{k_L} - k_H$, so the punished bank L earns b. The truthtelling constraint for the bank L (8) 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, (8) 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 (8) boils down to $x = \frac{1+\delta-q\gamma}{q\gamma\delta}(\underline{k_L} - k_H)$. Fifth, (9) can be ignored because it is slack when the regulator finds optimal to set sensitive capital requirements. To see this suppose that optimal $k_H < \underline{k_L}$, as well as q and x were such that (9) 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 of the above observations, inserting $x = \frac{1+\delta-q\gamma}{q\gamma\delta}(\underline{k_L} - k_H)$ into the objective function (6) and into (10) as well as ignoring constants in the objective function the maximization problem (6)-(11) boils down to:

$$\max_{k_H,q} \frac{1-\gamma-\delta(2\gamma-1)}{\gamma}k_H + q((1-\gamma)(\underline{k_L} - k_H) - m) \tag{21}$$

subject to

$$\underline{k_L} \geq k_H \geq \underline{k_H}, 1 \geq q \geq \widetilde{q}(k_H) \equiv \frac{1}{\gamma}\frac{(\underline{k_L} - k_H)(1+\delta)}{\underline{k_L} - k_H + \delta(1-k_H)}. \tag{22}$$

The lower bound on q, $\widetilde{q}(k_H)$, comes from inserting $x = \frac{1+\delta-q\gamma}{q\gamma\delta}(\underline{k_L} - k_H)$ into (10). We consider two cases.

Case (1): γ is such that $1 \geq \widetilde{q}(\underline{k_H})$ holds, i.e., $k_H = \underline{k_H}$ is feasible for some $q < 1$. Solving $1 \geq \widetilde{q}(\underline{k_H})$ for γ delivers that it is equivalent to $\gamma \in \left[\frac{(r_H-r_L)(1+\delta)}{r_H-r_L+\delta(1-\underline{k_H})}; 1\right)$ if $\frac{(r_H-r_L)(1+\delta)}{r_H-r_L+\delta(1-\underline{k_H})} > \frac{1}{2}$ or to $\gamma \in \left(\frac{1}{2}; 1\right)$ if $\frac{(r_H-r_L)(1+\delta)}{r_H-r_L+\delta(1-\underline{k_H})} \leq \frac{1}{2}$.

Claim The maximization problem (21)-(22) 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 (21) 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 (21) is linear in k_H. We can disregard the solution $k_H = \underline{k_L}$ and $q = 1$, because it would be socially wasteful to conduct regulatory inspection when $k_H = k_L = \underline{k_L}$. Third, for $q = \widetilde{q}(k_H)$, the solution is again either $k_H = \underline{k_H}$ or $k_H = \underline{k_L}$, because (21) is convex in k_H for $q = \widetilde{q}(k_H)$. To see this we insert $q = \widetilde{q}(k_H)$ in (21) 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 $k_H \in \left[\underline{k_H}; \underline{k_L}\right]$. Hence, we get that optimal $q = \widetilde{q}(\underline{k_H})$ for $k_H = \underline{k_H}$ and $q = 0$ for $k_H = \underline{k_L}$. These three observations imply the claim. ■

Which of the three solutions (i)-(iii) delivers higher welfare is determined by comparing the values of (21) 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): γ is such that $1 < \widetilde{q}(\underline{k_H})$ holds, i.e., for $k_H = \underline{k_H}$ there are no $q \in [0; 1]$ and $x \leq 1 - k_H$ for which (8) holds. $1 < \widetilde{q}(\underline{k_H})$ is equivalent to $\gamma \in \left(1/2; \frac{(r_H-r_L)(1+\delta)}{r_H-r_L+\delta(1-\underline{k_H})}\right)$, provided that the last interval is not empty, which occurs for $\underline{k_L} > \underline{k_H} + \frac{\delta}{1+2\delta}\left(1-\underline{k_H}\right)$. The lowest k_H for which (8) binds 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 (22) for maximization of (21) 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 claim from case (1) 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 (21) at these 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 solution to $\delta - \frac{(1-\gamma)^2}{(2\gamma-1)} \geq 0$, which determines whether $m_{lr} \geq 0$. Observe that the same inequality determines whether $m_1 \geq 0$. $m_{lr} = m_1$ 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 (6)-(11) for $m > m(\gamma)$. $k_H = k_H^{LR} = \underline{k_L} - \frac{\gamma\delta(1-\underline{k_L})}{(1-\gamma)(1+\delta)} > \underline{k_H}$, $k_L = \underline{k_L}$ 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 Proposition 2

The proof of the result consists of four steps. First, we show that the optimal k_L is again $\underline{k_L}$ as in case without the secondary market. Second, we show that the truthtelling unravels for $s = 1$ and $k_i^S = 1$. Third, we show that in general (for any $k_i^S \geq 1$) the bank L's incentive to misreport is higher when the bank H sells than when it keeps the project. Fourth, we show that making the bank H sell the project cannot increase its return beyond the return achieved in the case without the secondary market. All these claims together imply that the regulator should make the bank H keep the project under sensitive capital requirements.

First, we show that the optimal k_L is $\underline{k_L}$. In order to provide the bank L with the highest incentive to report true i the regulator would like to set such k_L and k_L^S that the bank L's payoff from reporting truthfully is the highest. (12) and $\delta > 0$ imply that the highest return of each bank i is when the bank i keeps the project with $k_i = \underline{k_i}$ for any k_i^S. Hence, the bank L's highest return is then $r_L - \delta\underline{k_L}$, which is the same return the bank L obtains in social optimum when there is no secondary market.

Second, 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 that each bank reports true i and $k_H \in \left(\underline{k_H}; \underline{k_L}\right)$ is such that the bank H sells ((12) implies that such k_H is higher than $\underline{k_H}$). If k_H is such that the bank H prefers to sell, its return from selling at $t = 0$ cannot be lower than its return from keeping:

$$\left(P_H^* - 1\right)(1 + \delta) \geq r_H - \delta k_H. \tag{23}$$

Both sides of this inequality are derived by subtracting the opportunity cost of capital at $t = 0$, $k_H(1 + \delta)$, from (13) and (14) for $i = H$ and using $k_i^S = 1$. Moreover, the punished bank H that sells receives the same return as the unpunished bank H, $(P_H^* - 1)(1 + \delta)$ (subtract $(k_H + x)(1 + \delta)$ from (17) for $s = 1$ and $k_i^S = 1$). The punished bank H also wants to sell because

$$\left(P_H^* - 1\right)(1 + \delta) \geq r_H - \delta k_H > r_H - \delta\left(k_H + x\right),$$

where $r_H - \delta(k_H + x)$ is its return when it keeps the project after recapitalization with x.

The bank L anticipates at $t = 0$ that the unpunished and punished bank H will sell at $t = \frac{1}{2}$. Hence, the bank L's expected return from misreporting at $t = 0$ is also $(P_H^* - 1)(1 + \delta)$, because it receives the same return as the bank H no matter whether it is punished or not. Moreover, $r_L - \delta\underline{k_L}$ is the bank L's highest return from reporting true i. Hence, (23), $k_H \in \left(\underline{k_H}; \underline{k_L}\right)$, $r_H > r_L$ and $\underline{k_i} = b - r_i$ imply together that the bank L's return from misreporting is higher than from reporting true i:

$$\left(P_H^* - 1\right)(1 + \delta) \geq r_H - \delta k_H > r_L - \delta\underline{k_L}.$$

Hence, the bank L always misreports and truthtelling unravels, which contradicts the initial assumption that the bank L could report true i for $s = 1$ and $k_i^S = 1$. This proves the claim that truthful reporting is impossible without any restrictions on selling.

Third, we show that the bank L has stronger incentive to misreport if the bank H sells than if it keeps the project for any $k_H^S \geq 1$. If the bank H sells, k_H and k_H^S are such that its return from selling at $t = 0$ is not lower than the return from keeping the project, i.e., $P_H^*(1 + \delta) - 1 - k_H^S\delta \geq r_H - \delta k_H$.

The return from selling is derived as above for any $k_H^S \geq 1$. Now if the bank L misreports, it gets $P_H^* (1+\delta) - 1 - k_H^S \delta$ if the bank H sells, and it gets $b - (1+\delta) k_H$ if the bank H keeps (due to $k_H < \underline{k_L}$ the bank L does not monitor). Because it holds that $r_H - \delta k_H > b - (1+\delta) k_H$ (it is equivalent to $k_H > \underline{k_H}$), the bank L's return from misreporting when the bank H sells is higher than the return when the bank H keeps: $P_H^* (1+\delta) - 1 - k_H^S \delta \geq r_H - \delta k_H > b - (1+\delta) k_H$. The same line of argument can be used in case the bank H is punished. Hence, because the return from misreporting is higher for the punished and unpunished bank L when the bank H sells than when it keeps, and because the highest bank L's return from reporting the truth is the same as in the case when the secondary market does not exist, it follows that the regulator has to spend more resources (higher q or x) to satisfy the truthtelling constraint for the bank L for a given k_H than in the case when the bank H keeps its project.

Fourth, we show that making the bank H sell the project cannot increase its return beyond the return achieved in the case without the secondary market. It follows from (12) as discussed above. Because the highest return from selling is always lower than the highest return from keeping for any $k_H \geq \underline{k_H}$, the regulator can always replicate any return the bank H gets from selling by changing k_H and k_H^S in such a way that the bank H keeps the project.

Hence, the last two steps of the proof imply that the regulator should set such k_H and k_H^S that the bank H always keeps the project. Because the bank H that is punished is more willing to sell than if it is not punished we get the result that $k_H^S > 1 + k_H + x - \underline{k_H} - \frac{1+\delta}{\delta}\left(\lambda - \frac{\delta b}{1+\delta}\right)$ is sufficient enough to eliminate the incentive to sell for the bank H whether it is punished or not (i.e. (16) does not hold).■

Proof of Lemma 1

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 use selling as a penalty. The reason is that the project sells at a discount λ to its fair value. Whether selling and prohibition of payouts is indeed a greater penalty for the bank L than keeping the project depends on the comparison of its return. If the punished bank L's keeps the project its return is the same as in (8), $r_L - \delta (k_H + x)$. The punished misreporting bank L that is required to sell sells its project for the price of the project H, because in the truthtelling equilibrium only the bank H is punished. Moreover, the punished bank L has to keep the proceeds from selling, P_H^*, in the bank. Otherwise, by paying out proceeds from selling and investing them in the alternative project it could recuperate some of it loss on selling. Hence, the punished bank L's return from misreporting when $s = 1$ is

$$P_H^* - (1 - k_H - x) - (1 + \delta)(k_H + x) = r_H - \lambda - \delta(k_H + x).$$

The regulator will not use selling as penalty if the misreporting bank L's return from selling, $r_H - \lambda - \delta(k_H + x)$, is not lower than its return from keeping, $r_L - \delta(k_H + x)$. Such an inequality is equivalent to $\lambda \leq r_H - r_L$. If the regulator required selling as penalty for $\lambda \leq r_H - r_L$, the bank L's truthtelling constraint would tighten and the bank H's expected return from reporting true i would decrease, which would lead to a decrease in social welfare. If the regulator does not require to sell as penalty for $\lambda \leq r_H - r_L$, then in combination with claims from the proof of Proposition 2, the truthtelling constraints are the same as in Section 2. The reason is that it is socially optimal for each bank i to keep its project under sensitive capital requirements. Hence, the sensitive capital requirements from Proposition 1 are optimal again.

For $\lambda > r_H - r_L$ selling can be a penalty for the bank L as it provides lower return from being punished when compared with the case when there is no secondary market. Selling as penalty leads to additional solutions for the sensitive capital requirements given that the additional penalty gives the regulator more scope to punish the bank. However, we ignore this case because complicates the derivations without changing the most important result of the paper, Proposition 2.■

Proof of Lemma 2

We denote the reservation price of the bank i from expression (20) as P_i^R. Given that the investors know k and k^S they know the banks' reservation prices P_i^R. Because $P_H^R \geq P_L^R$ the investors will pay the price that reflects the expected return for the project, $1 + \pi r_H + (1 - \pi) r_L - \lambda$, only if the bank H is willing to sell at such a price. Hence, both banks sell if $1 + \pi r_H + (1 - \pi) r_L - \lambda \geq P_H^R$. After substituting for P_H^R and solving for k this inequality is equivalent to

$$k \geq \underline{k_H} + \left(k^S - 1\right) + \frac{1+\delta}{\delta}\left[\left(\lambda - \frac{\delta b}{1+\delta}\right) + (1-\pi)(r_H - r_L)\right] \equiv k_1\left(k^S\right). \tag{24}$$

It holds that $k_1\left(k^S\right) > \underline{k_H}$ because of (1), (12) and $k^S \geq 1$ (the selling bank has to have enough capital to repay depositors as shown in the Section 3.2.1). It has to be noted that for $k < \underline{k_H}$ the bank H would always keep the project due to (12).

If (24) does not hold, then only the bank L would be willing to sell for $1 + \pi r_H + (1-\pi) r_L - \lambda$, but then the investors would make losses given that they would buy the project L. Hence, the investors anticipate this and offer $1 + r_L - \lambda$ instead. The bank L will sell only if $1 + r_L - \lambda \geq P_L^R$ or

$$k \geq \underline{k_L} + \left(k^S - 1\right) + \frac{1+\delta}{\delta}\left(\lambda - \frac{\delta b}{1+\delta}\right) \equiv k_2\left(k^S\right).$$

It holds that $k_2\left(k^S\right) > \underline{k_L}$ because of (12) and $k^S \geq 1$. Moreover, the case where only the bank L sells exists only if $k_1\left(k^S\right) > k_2\left(k^S\right)$, which is equivalent to $\pi < \min\left[\frac{1}{1+\delta}; \pi_0\right]$. It follows also that for $k < \min\left[k_1\left(k^S\right); k_2\left(k^S\right)\right]$ the bank L will also keep the project.■

Proof of Lemma 3

We prove the result in two steps. First, we derive the socially optimal insensitive capital requirements. Second, we show that sensitive capital requirements cannot deliver higher social welfare than the insensitive.

Step 1. Under insensitive capital requirements the regulator knows the outcomes on the secondary market for each k and k^S according to Lemma 2. Hence, social welfare is the bank's expected return at $t = 0$ under each of three outcomes on the secondary market:

$$\begin{cases} \pi\left(r_H - \delta k\right) + (1-\pi)\left(r_L - \delta k\right), \text{ if } k < \min\left[k_1\left(k^S\right); k_2\left(k^S\right)\right] \\ \pi\left(r_H - \delta k\right) + (1-\pi)\left[\left(1 + r_L - \lambda\right)(1+\delta) - 1 - k^S\delta\right], \text{ if } k \in \left[k_2\left(k^S\right); k_1\left(k^S\right)\right) \\ \left(1 + \pi r_H + (1-\pi) r_L - \lambda\right)(1+\delta) - 1 - k^S\delta, \text{ if } k \geq k_1\left(k^S\right). \end{cases}$$

If none of the banks sells ($k < \min\left[k_1\left(k^S\right); k_2\left(k^S\right)\right]$), then each bank's return is $r_i - \delta k$. Each bank keeping the project monitors because (5) implies that the regulator sets $k \geq \underline{k_L}$ when i stays bank's private information. If only the bank L sells ($k \in \left[k_2\left(k^S\right); k_1\left(k^S\right)\right)$), the bank H's return is $r_H - \delta k$ and the bank L's return is $\left(1 + r_L - \lambda\right)(1+\delta) - 1 - k^S\delta$ (we subtract $k(1+\delta)$ from (13) for $i = L$). If each bank i sells ($k \geq k_1\left(k^S\right)$), social welfare is the expected bank's return from selling (we subtract

$k(1+\delta)$ from (18) for $P = 1 + \pi r_H + (1-\pi) r_L - \lambda$):

$$\begin{aligned} & (1 + \pi r_H + (1-\pi) r_L - \lambda + k)(1+\delta) - 1 - k^S \delta - k(1+\delta) \\ = \; & (1 + \pi r_H + (1-\pi) r_L - \lambda)(1+\delta) - 1 - k^S \delta. \end{aligned}$$

For each bank i the return from selling is the same because both banks sell for the same price and are subject to the same capital requirements.

In order to get the optimal capital requirements, we compare the highest social welfare for each of the three outcomes on the secondary market. We pin down the exact values for the highest social welfare for each outcome by determining the corresponding values of k and k^S. First, when both banks keep the project ($k < \min\left[k_1\left(k^S\right); k_2\left(k^S\right)\right]$), the lowest k the regulator can set is $\underline{k_L}$. Otherwise, the bank L would not monitor the project and default, which is not optimal under (5). Second, when only the bank L sells the project, the optimal k^S is 1. This is the lowest amount of costly capital the selling bank needs to have in order to repay its depositors. The lowest possible k the regulator can choose is $k_2\left(k^S = 1\right)$. Otherwise, the bank L would prefer to keep. Third, for the outcome in which at least one bank sells the optimal k^S is 1 for the same reason as above.

Now, using the above three observations we can show after some algebra that under assumption (12) the highest social welfare for the outcome when both banks keep is never lower than for the outcome with only the bank L selling. Hence, it suffices to compare the highest social welfare for the outcomes in which both banks either sell or keep. Such a comparison yields that the highest social welfare is higher when both banks sell for $\lambda < \frac{\delta[b+\pi(r_H - r_L)]}{1+\delta}$. Such an outcome could be implemented by setting any k for which $1 + \pi r_H + (1-\pi) r_L - \lambda \geq P_H^R$ for $k^S = 1$. Solving this inequality shows that it holds for $k \geq \underline{k_H} + \frac{1+\delta}{\delta}\left[\left(\lambda - \frac{\delta b}{1+\delta}\right) + (1-\pi)(r_H - r_L)\right]$. Hence, we obtain that social welfare is the highest when both banks sell for $k \geq \underline{k_H} + \frac{1+\delta}{\delta}\left[\left(\lambda - \frac{\delta b}{1+\delta}\right) + (1-\pi)(r_H - r_L)\right]$, and when both keep otherwise.

Step 2. Now we show that sensitive capital requirements cannot deliver higher social welfare than the insensitive. We do so by showing the social welfare under sensitive capital requirements is never higher than social welfare under insensitive capital requirement $\underline{k_L}$ when the both banks keep the project, $W_0 = \pi(r_H - \delta \underline{k_L}) + (1-\pi)(r_L - \delta \underline{k_L})$. W_0 is the lowest bound for social welfare under insensitive capital requirements as shown in step 1.

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, we are interested only in the case when sensitive capital requirements are such that each bank reports truthfully. In a truthtelling equilibrium there are four potential outcomes on the secondary market: each bank i sells/keeps, one bank sells and the other keeps.

First, we show that if k_i and k_i^S are such that in a truthtelling equilibrium the bank H keeps the project (regardless of whether the bank L keeps or sells), social welfare cannot be higher than W_0. The reason is that the regulator has to choose $k_H \geq \underline{k_L}$ and $k_L \geq \underline{k_L}$, which deliver welfare not higher than W_0. For any $k_H < \underline{k_L}$ the bank L would find it profitable to mimic the bank H, keep the project and default, which is socially inefficient due to (5). The bank L prefers to mimic the bank H, because its return from misreporting is then $b - (1 + \delta) k_H$, which is higher than its highest payoff from reporting truthfully, $r_L - \delta \underline{k_L}$. $k_H \geq \underline{k_L}$ also implies that $k_L \geq \underline{k_L}$.

Second, we analyze the case when each bank i sells. Denote as V_j the bank i's return at $t = 0$ from selling the project after reporting j, $V_j = P_j^* (1 + \delta) - 1 - k_j^S \delta$. When each bank i sells, selling has to deliver higher return than keeping for each bank i that reports truthfully, $j = i$, $V_i \geq r_i - \delta k_i$. The bank L reports its true type if the return from reporting L and selling, V_L, is not lower than the return 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 due to (12) and $k^S \geq 1$ it holds that $V_L < r_L - \delta \underline{k_L}$. Combining $V_L \geq V_H$ with $V_L < r_L - \delta \underline{k_L}$ delivers that the bank H's return V_H in such a truthtelling equilibrium must be lower than $r_L - \delta \underline{k_L}$: $r_L - \delta \underline{k_L} > V_L \geq V_H$. But $r_L - \delta \underline{k_L}$ is also lower than the bank H's return from keeping under $k = \underline{k_L}$, $r_H - \delta \underline{k_L}$. Hence, each bank i gets a lower return than $r_i - \delta \underline{k_L}$ implying that such a truthtelling equilibrium delivers welfare lower than W_0.

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 from reporting H and selling (keeping can be ignored for the same reason as above), $r_L - \delta k_L \geq V_H$. Hence, such an equilibrium would again deliver welfare lower than W_0 for the same reasons as in the previous case (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 Proposition 3

We know already from Lemma 1 that the socially optimal sensitive capital requirements are the same as in Proposition 1 for $\lambda \leq r_H - r_L$. In order to determine whether the sensitive or insensitive capital requirements are optimal when the secondary market exists, we have to compare again social welfare from both types of capital requirements.

For $\lambda \geq \frac{\delta[b+\pi(r_H - r_L)]}{1+\delta}$ 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 $\lambda < \frac{\delta[b+\pi(r_H - r_L)]}{1+\delta}$ the insensitive capital requirements deliver higher welfare than in the case without the secondary market. Hence, there is a new function $m_S(\gamma)$ such that the threshold for inspection cost m for which the insensitive capital requirements yield higher welfare than the sensitive is lower than in the case without the secondary market. Hence, it holds $m_S(\gamma) < m(\gamma)$ whenever $m(\gamma) > 0$. Moreover, $m_S(\gamma) < m(\gamma)$ implies that the thresholds for γ that determine the parts of the function $m_S(\gamma)$ need to increase.

Now we derive $m_S(\gamma)$ by comparing social welfare from the sensitive capital requirements with social welfare from the insensitive capital requirements under the outcome that each bank i sells. In case of the insensitive capital requirements the highest social welfare when both banks sell is given by the expression from Lemma 3 for social welfare when both banks sell and $k^S = 1$:

$$(1 + \pi r_H + (1-\pi)r_L - \lambda)(1+\delta) - 1 - \delta = (\pi r_H + (1-\pi)r_L - \lambda)(1+\delta)$$

As in Proposition 1 we do not provide the detailed algebra for comparison of social welfare expressions.

The insensitive capital requirements deliver higher social welfare than the sensitive capital requirements with $k_H = \underline{k_H}$ (there are two possibilities of such a solution which differ in optimal q and x as shown in Proposition 1) for $m > \max\left[m_1 - z; m_2 - \frac{z}{\widetilde{q}(\underline{k_H};0)}; 0\right]$, where $z = \frac{1+\delta}{\pi}\left(\frac{\delta[b+\pi(r_H-r_L)]}{1+\delta} - \lambda\right) > 0$ for $\lambda < \frac{\delta[b+\pi(r_H-r_L)]}{1+\delta}$. 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

$m > \max\left[m_{lr} - z; 0\right]$. The inequality $m_{lr} - z \geq 0$ holds for $\gamma \in [\gamma_{1S}; 1]$, where $\gamma_{1S} > \gamma_1$. $\gamma_{1S} > \gamma_1$ holds because z is a constant independent of γ and $m_{lr} - z$ is just a downward shift of m_{lr} that is increasing in γ. 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 $z \geq 0$. Summarizing all results give us the following function:

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

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 $\gamma_{1S} < \gamma_2$.■

Appendix B - Change in the timing and stochastic returns

In one setup we show the following: (i) stochastic returns only add complexity to the model, and (ii) allowing for learning i after financing the project is not material for the results. The modified timing of the model presented in the Figure 5 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. 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 $1 - l$ with probability p_i. If the bank doesn't monitor the project, the bank gets b and the project pays $1 - l$ with probability 1. At $t = 0$ the probability that the project is H (L) at $t = 1$ is π $(1 - \pi)$ and $p_H < p_L$. To simplify the exposition we assume that $l = 1$. The cost of capital is δ at $t = 0$ and $t = 1$. The analogue of (1) is $(1 - p_H)\, r > (1 - p_L)\, r > \delta$.

If the regulator knew i at $t = 1$ k_i and d_i 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 monitors 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 $t = 1$ after the bank learns i, where with k_i and d_i the bank has to finance the project of size 1 and a fair deposit insurance premium $p_i d_i$. Because 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 $\underline{d_i}$ are

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

It is convenient to observe that $\underline{k_i}$ combines capital outlay and the deposit insurance fee (see Rochet (2004) for an identical treatment). Alternatively, we could have separated explicitly capital requirements from deposit insurance premium, but the results would stay the same. To justify the capital regulation we use an analogue of (2):

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

which guarantees that $\underline{k_i} > 0$. Observe that $\underline{k_H} < \underline{k_L}$ because $p_H < p_L$. Hence, the minimum capital level needed for monitoring increases with riskiness of the project.

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 for the bank L:

$$\begin{aligned} & (1 - p_L)\left(1 + r - \frac{1 - \underline{k_L}}{1 - p_L}\right) - (1 + \delta)\left(\underline{k_L} - k_0\right) \qquad (25) \\ \geq (1 - q\gamma)\left[b - (1 + \delta)(k_H - k_0)\right] \quad & + q\gamma\left[(1 - p_L)\left(1 + r - \frac{1 - k_H - x}{1 - p_H}\right) - (1 + \delta)(k_H + x - k_0)\right]. \end{aligned}$$

The constraint already takes into account that $k_H \leq \underline{k_L} \leq x + k_H$ is required for the constraint to hold (as in the baseline model), that the optimal k_L is $\underline{k_L}$ and $\underline{d_i} = \frac{1 - \underline{k_i}}{1 - p_i}$. The left-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 right-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 bank H's probability of default. 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:

$$x\left(\delta + \frac{p_L - p_H}{1-p_H}\right) \geq \frac{p_L - p_H}{1-p_H}(1-k_H) + \left(\frac{1+\delta}{q\gamma} - 1\right)\left(\underline{k_L} - k_H\right). \tag{26}$$

(26) is slightly more complicated than (8) that is equivalent to $x\delta \geq \left(\frac{1+\delta}{q\gamma} - 1\right)\left(\underline{k_L} - k_H\right)$. The reason is that the misreporting bank L not only saves on costly capital but is also charged with a deposit premium paid by the bank H. However, including the deposit insurance premia won't affect the main results at all. It would only make the algebra more tedious. Moreover, k_0 does not appear in (26). This implies that the initial capital structure at $t = 0$ does not play any role for the bank's incentive to misreport once i is revealed to the bank at $t = 1$. This is due to the fact that δ is independent of k_0, k_H, k_L, and x. Hence, once δ stays exogenous 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.

Appendix C - Micro-foundations of Assumption (12)

We assume that the investors can pay maximally only a fraction of the project i's return $1 + r_i$: The project's value for the investors equals the expected return of the project diminished by an exogenous discount λ. This assumption can be justified in several ways: The investors are not the most efficient users of the project, they have to perform costly monitoring to receive the maximal project's return, or they have a positive net opportunity cost of investing in the project.

We present the algebra for the case when the investors know i (similar results obtain when the investors do not know i at the time of purchase). If the investors are not the most efficient users of the project, they are not able to generate the full return. As in Acharya and Yorulmazer (2007) the project's return is diminished by an exogenous discount $\lambda > 0$.

In case the investors can exert costly monitoring effort enhancing the project's return (as in Parlour and Winton (2008)), the competition will ensure they pay the highest of the two returns with or without monitoring: $P = \max\left[1 + r_i - c; p\left(1 + r_i\right)\right] = 1 + r_i - \min\left[c; \left(1 - p\right)\left(1 + r_i\right)\right]$, where $c > 0$ is the investors' monitoring cost and $p \in [0, 1)$ is probability of success of the unmonitored project (for illustrative purposes we use here the general formulation of monitoring effort departing from the baseline model in which the bank chooses between $1 + r_i$ or private benefits b). Hence, $\lambda = \min\left[c; \left(1 - p\right)\left(1 + r_i\right)\right] > 0$.

If the investors' capital comes with a net opportunity cost of $\beta > 0$, then the competitive investors pay a price given by their break even condition: $1 + r_i = P\left(1 + \beta\right)$ or $P = 1 + r_i - \frac{\beta(1+r_i)}{1+\beta}$. Hence, $\lambda = \frac{\beta(1+r_i)}{1+\beta} > 0$.

Appendix D - Portfolio of Projects

We assume that instead of the project's quality the bank i learns at $t = 0$ a share α_i, $i = H, L$, of its portfolio composed of the project H and the rest, $1 - \alpha_i$, of L. By using H and L to describe banks as well as projects, we avoid new notation and preserve correspondence between the baseline and extended setup. To make the notation more accessible we denote type of the project with $j = H, L$. With probability π the bank is H with α_H of the project H, and with probability $1 - \pi$ the bank is L with α_L of the project H, where $\alpha_H > \alpha_L$.

In reality, the capital requirements are assigned on a asset-by-asset-basis rather than on the whole portfolio. Hence, a higher share of riskier assets would result in a higher aggregate capital requirement for the bank. Our setup with moral hazard provides the same implications. The regulator prescribes for every project j the amount of capital the bank needs to finance the project. In our moral hazard setup it would mean the regulator looks for such an amount of capital that the bank has an incentive to monitor a given project. If we assume that it is socially optimal that the bank monitors each of its projects, then the minimum amount of capital that provides the bank with an incentive to monitor a given project j is simply given by $\underline{k_j}$ as in the baseline model. Hence, the aggregate amount of capital for the bank i that reports its true type is $\overline{k}_i \equiv \alpha_i k_H + (1 - \alpha_i) k_L$, where $k_j \geq \underline{k_j}$ for each project j. $\overline{k}_i$ increases with the share of the project L in the bank's portfolio. Establishing this fact is the crucial part of our claim that we can generalize the model to the case of a portfolio of projects. The reason is that the regulator will aim to set sensitive capital requirements k_j for which the bank H will be required to hold less capital in aggregate than the bank L. This will allow the investors to infer correctly from the bank's aggregate capital level the type of the bank.

In what follows we do not analyze the whole model, but only highlight the crucial steps to show that the baseline model is just a special case of this extended setup in which $\alpha_H = 1 - \alpha_L = 1$. As in the baseline model the optimal capital requirement for the project L, k_L, is the minimum amount of capital $\underline{k_L}$.

When there is no secondary market the truthtelling constraint for the bank L is analog to (8)

$$\overline{r}_L - \delta \overline{k}_L \geq (1 - q\gamma) \left[b - \overline{k}_H (1 + \delta) \right] + q\gamma \left(\overline{r}_L - \delta (\overline{k}_H + x) \right),$$

where $\overline{r}_L = \alpha_L r_H + (1 - \alpha_L) r_L$. To obtain the above inequality we assume that if the misreporting bank L monitors only one project the return on this project is not sufficient to cover deposits that are used to finance both projects, i.e. $1 - \overline{k}_H > \max \left[\alpha_L (1 + r_H); (1 - \alpha_L)(1 + r_L) \right]$. Hence, the misreporting bank L prefers to not monitor any projects. This is a simplifying assumption which reduces the amount of cases to be analyzed. Then the regulator can solve an analog maximization problem to (6)-(11) with the only difference that it determines this time capital requirement k_j for the project j rather than bank i. Of course, determination of k_j implies also $\overline{k}_i$ of which it is a component. Especially, for sufficiently low γ as in the case 2 of Proposition 1 the regulator would like to set $k_H > \underline{k_H}$, that might prompt the bank H to sell its project H when the secondary market exists.

When there is a secondary market, the crucial result of the baseline model is that the bank L's incentive to misreport is higher when the bank H sells than when it does not. The reason is that the bank H sells its project that is more valuable than the bank L's project. Now we show that it is also the case in the setup with portfolio of projects.

As in the baseline model, in case of a portfolio of projects the bank H has an incentive to sell, when capital requirements for keeping the portfolio intact are too high from its perspective. The difference to the baseline model is that the bank H has more alternatives on the secondary market: It can sell the whole portfolio, only the project H or only the project L. In case $q > 0$ the investors infer correctly from the bank's aggregate capital level not only the type of the bank but also which alternative it will choose on the secondary market. The reason is that the investors know all the parameters of the model and the capital requirements to which each bank is subject. However, if we maintain the assumption (12), then we will get again the result that the bank H will be willing to sell only the project H. To simplify the argument we will assume that the bank has to retain only the lowest possible amount of capital after the sale, i.e., such an amount that suffices to repay deposits with which the sold project was financed (this is equivalent to $k_i^S = 1$ in the baseline model). Moreover, we observe that once the bank sells one project, it will still maintain the incentive to monitor the other project, because the capital used to finance this project remains intact. Hence, if the bank H sells its project H its payoff at $t = \frac{1}{2}$ is

$$\alpha_H \left(P_H^* - (1 - k_H)\right)(1+\delta) + (1 - \alpha_H)(r_L + k_L), \tag{27}$$

where the first term is the gross return on the investment of the rest of the proceeds from sale of the project H after the repayment of the underlying deposits, and the second term is the return on the kept project L. Using the fact that again the optimal k_L is $\underline{k_L}$ and $P_j^* = 1 + r_j - \lambda$ (27) is equivalent to

$$\alpha_H (r_H + k_H) + (1 - \alpha_H)\left(r_L + \underline{k_L}\right) + \alpha_H \left[k_H - \left(\underline{k_H} + \frac{1+\delta}{\delta}\left(\lambda - \frac{\delta b}{1+\delta}\right)\right)\right],$$

where the first two terms represent the bank H's payoff at $t = \frac{1}{2}$ from keeping both projects. Hence, it is clear that the bank H sells its project H for the same k_H as in the baseline model (the last term of the last expression is analog to (15) for $k_i^S = 1$). Similarly if the bank H sells only the project L its payoff at $t = \frac{1}{2}$ is

$$\begin{aligned} & (1-\alpha_H)\left(P_L^* - \left(1 - \underline{k_L}\right)\right)(1+\delta) + \alpha_H (r_H + k_H) \\ = \; & \alpha_H (r_H + k_H) + (1-\alpha_H)\left(r_L + \underline{k_L}\right) - (1-\alpha_H)(1+\delta)\left[\lambda - \frac{\delta b}{1+\delta}\right]. \end{aligned}$$

Hence, the bank H does not want to sell the project L, because due to (12) its return from selling it is lower than when it keeps both projects, $\alpha_H (r_H + k_H) + (1 - \alpha_H)\left(r_L + \underline{k_L}\right)$. This also implies that selling both projects is not profitable because the bank would make losses on the sold project L. This proves our claim that also in the extended setup with portfolio of projects the bank H would like to sell its project H. Moreover, (12) again implies the secondary market would not provide sufficient social benefits to counteract the increased bank L's incentive to misreport.

Appendix E - Uninsured deposits

Observe that the same truthtelling constraint as (25) arises when the deposits are uninsured. The reason is that the regulator by charging the fair deposit insurance premium in the truthtelling equilibrium acts in the same way as the uninsured depositors do: the regulator demands fair compensation for the bank's riskiness. The only difference is that uninsured depositors infer i from the bank's capital level after regulatory inspection. To be more precise, the bank i that finances a project of size 1 has $1 - k_i$ deposits for which it has to pay a gross interest rate $\frac{1}{1-p_i}$ per unit to compensate the depositors for probability of default. At the same time the minimum capital level that the bank i with uninsured deposits needs to monitor 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. Finally, because uninsured 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 $\frac{1}{1-p_H}$ per unit borrowed. Hence, in case the bank L misreports it lowers its capital requirement but it also pays lower interest rate on deposits. This establishes the equivalence of the case between insured and uninsured deposits when the regulator provides the information about i.

Figures

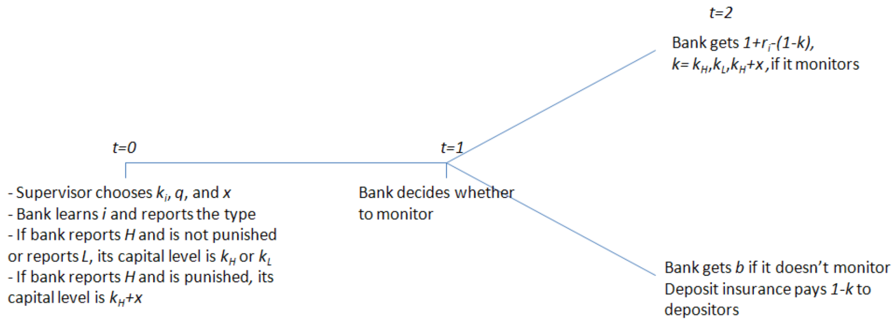

Figure 1: The timeline of the events for the regulated bank.

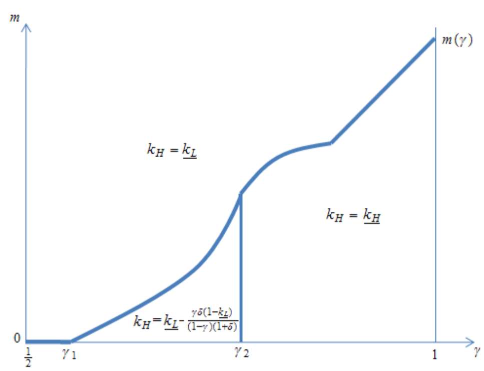

Figure 2: Proposition 1 in case $\gamma_2 > \gamma_1$. The figure illustrates the choice of socially optimal k_H as a function of inspection noise (γ) and inspection cost (m). The figure distinguishes three regions: a region defined by $m > m(\gamma)$ in which the capital requirements are insensitive ($k_H = \underline{k_L}$); 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 ($k_H = \underline{k_H}$).

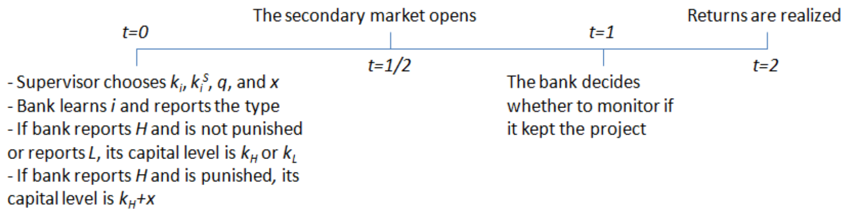

Figure 3: The timeline of the events for the regulated bank when there is secondary market.

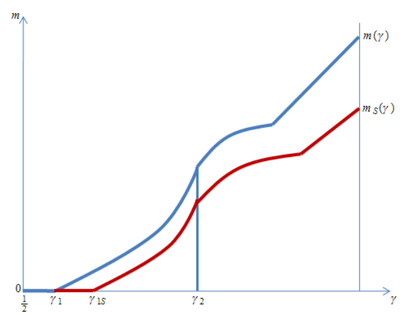

Figure 4: Comparison of solutions without and with secondary market for $\pi \in \left[\max\left\{\pi_0; \frac{1}{1+\delta}\right\}; \pi_C\right)$ and $\underline{k_L} \in \left(\underline{k_H}; \min\left\{1; \frac{1+\delta+\underline{k_H}+C}{2+\delta}\right\}\right)$. The blue (upper) curve is defined 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.

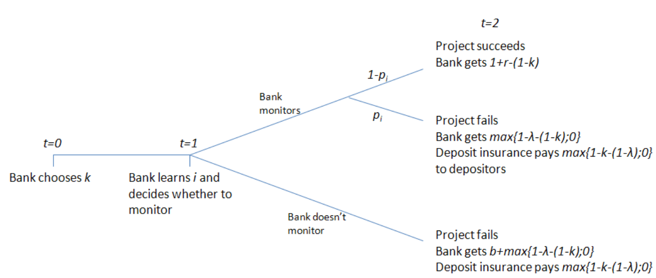

Figure 5: Modified time line