Securitization and Compensation in Financial Institutions*

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Abstract

We analyze the interaction between financial institutions' internal compensation policy, the quality of loans, and their securitization decision. We also assess the case for requiring financial institutions to defer bonus pay so as to make incentives more commensurate with the longer-term risk of their transactions. While mandatory deferred compensation can improve the quality of loans, we also show when it has the opposite effect. We further analyze when mandatory deferred compensation can complement a policy that requires financial institutions to retain a minimum exposure to their originated loans, and we discuss the impact of a tax on short-term bonus pay. Generally, our modeling framework allows us to study the interaction of financial institutions' internal agency problems with the external agency problem that arises from securitization.

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1 Introduction

The financial industry's bonus-driven compensation has been singled out as a key suspect responsible for the ongoing financial crisis. Consequently, both practitioners and academics demand regulatory intervention.[1] Arguably, at least in hindsight, financial institutions have taken on too much risk. Highly "front-loaded" compensation for (investment) bankers, traders, or mortgage brokers may have played a key role in this. Agents who are paid commissions, fees, or a bonus based mainly on yearly, or even shorter-term, revenues take little account of longer-term risk–e.g., the long-term performance of a loan.

Such compensation may be optimal for financial institutions that have a high appetite for risk. However, we show that when financial institutions securitize deals, they may end up with a compensation structure that, from the perspective of maximizing long-term profits, is too steep and too short-term-oriented. Thus, one contribution of this paper is to provide a consistent rationale for regulating compensation in the financial industry, even when we abstract from the presence of non-internalized "systemic effects" of risk taking.[2] However, we also derive conditions under which mandatory deferred compensation can "backfire" and even reduce the quality of loans, thereby increasing the likelihood of subsequent default. We further study how restrictions on compensation can complement restrictions that are imposed on securitization–e.g., by requiring financial institutions to keep a minimum exposure to their originated transactions.

We consider the compensation of an agent who could be an investment banker or loan officer, and we discuss below how our insights also apply, more broadly, to the compensation of financial institutions' senior management as the agent of shareholders. When processing a potential transaction, which involves costly effort, the agent acquires private information about the quality of the transaction. In the language of Berger and Udell (2002), the

[1]See, e.g., Rajan, Raghuram, "Bankers' pay is deeply flawed." *Financial Times*, 9 Jan 2008; Squam Lake Working Group on Financial Regulation (2010); or, even from the industry's perspective, Institute of International Finance (2008). For a discussion, see recently Core and Guay (2010).

[2]In particular, absent the failure of governance mechanisms, it seems not entirely convincing that financial institutions should be unable to choose optimal compensation schemes because they are in a rat race to attract the best staff. (See, e.g., Wolf, Martin, "Regulators should intervene in bankers' pay." *Financial Times*, 16 Jan 2008.) In fact, standard agency theory would predict, instead, a *positive* relationship between contractual efficiency and competition for labor when competition increases agents' reservation value. In Acharya and Volpin (2010) and Dicks (2010), a firm's choice of governance, which serves as a substitute for incentive pay, affects the outside option of other executives. Bebchuk and Spamann (2010) point out that, as in any high-leveraged firm, management pay that is designed to maximize shareholder value risks inducing behavior that is detrimental to debtholders.

agent's information is "soft"–i.e., "hard to quantify, verify and communicate through the normal transmission channels of a banking organization." The quality of transactions and loan-making can be improved when the bank makes use of this information. This is, however, costly for the following reason. In our model, generating a new transaction is costly for the agent. Providing the agent with the respective incentives endogenously biases him towards overstating the benefits from new transactions. It is costly for the bank to provide countervailing incentives for this, and much of our analysis will hinge on when the necessary *incremental* compensation costs are high - and on how this depends on regulation.

As we also discuss below in more detail, our model is more generally applicable, as it requires only that the agent can take private actions to influence loan quality. For instance, he also could conspire with potential borrowers and distort seemingly "hard" information.[3]

The agent's information advantage vis-à-vis the principal (the financial institution) constitutes a key measure of the *internal* agency problem. Such an internal agency problem arises, as the agent does not directly bear the risk associated with a new transaction. However, the originating institution may not remain fully exposed either, as it could securitize the generated assets or cash flows. In this case, there is an additional *external* agency problem. Our model studies the interaction of financial institutions' internal agency problem with their external agency problem arising from securitization.

In the model, the agent can receive an early bonus or a deferred bonus. Further, the financial institution controls how steep the agent's compensation is. When compensation is deferred, it can be made contingent on more information about the quality of the transaction–e.g., whether a borrower ultimately defaulted. However, deferring compensation is costly, as, in line with much of the literature (cf. Section 2), we presume that the agent has a higher time (or liquidity) preference than the principal–i.e., the financial institution.

The financial institution's second decision is whether and to what extent to securitize. We deal with both the case where the retained stake is observable by investors and the case where this is not observable, and we also discuss how the financial institution would

[3]For instance, with mortgage or consumer lending, this could involve providing borrowers with fake income slips or pretending that, if the actual income were low, the borrower was self-employed (cf. "FSA bans mortgage brokers for submitting false loan applications," FSA, 21 Feb 2008; or "Twelfth periodic mortgage fraud report," Mortgage Asset Research Institute, 2010).

optimally structure the issued securities. Securitization may benefit the financial institution by allowing it to diversify risk or relax funding constraints–in particular, in the face of regulatory capital requirements. For financial firms, securitization has become increasingly important and, compared to non-financial firms, is directly linked to credit origination as one of their primary fields of operations (cf., also, Loutskina, 2010 or Martín-Oliver and Saurina, 2007).

The anticipated level of securitization determines the optimal compensation strategy, while the price of the issued securities depends on the market's expectations about the internal incentives that the firm provides to its own agents. We first solve for the market equilibrium when regulators do not interfere. When the bank remains fully exposed to a new loan, as it does not securitize, it trades off the benefits of higher asset quality with higher costs of compensation. Benefits are, however, diluted when the bank anticipates securitizing a large fraction of its loans. In equilibrium, the bank will incentivize the agent to screen loans only when it retains a sufficiently large exposure. Also, only in this case will the bank possibly defer compensation so as to tie it more closely to the performance of loans or any other information on loan quality that may be revealed over time–e.g., through an internal loan review. Otherwise, given the agent's impatience, compensation will always be short-term.

The last observation suggests that through *forcing* the bank to defer compensation, the bank could be induced to use the additional information on the loan's performance and to incentivize the agent accordingly. We provide conditions for when this is, indeed, the case. Then, regulating compensation leads to an increase in loan quality. It mitigates a commitment problem that the originating institution has vis-à-vis the buyers of its securities. However, the opposite result also may arise, in which case, mandatory deferred pay reduces average loan quality and increases the likelihood of future default. We also find that, in our model, the risk of such unintended consequences is larger with a bonus tax compared to an outright requirement to defer bonus pay.

When regulating compensation has the described unintended consequences, it is in neither the industry's nor the regulator's interest. However, when regulation increases the average quality of loans, then even in the absence of external (systemic) effects that could arise from future loan default, the regulator may want to make deferred pay mandatory even when this is not in the bank's interest. This is more likely when some investors are not sufficiently wary of the incentives of the originating institution, either because they are unsophisticated or because their own incentives are distorted (e.g., Bolton et al., 2010a).

The interplay of the internal and external agency problems in our model allows us to study, as a second policy instrument, the imposition of a mandatory retention requirement for the originating firm. Such a policy is being discussed in the U.S. (cf. U.S. Treasury, 2009) and is part of a recent directive by the European Commission (EC, 2009). In our model, such a policy is more effective because it can not "backfire." However, we show that it could still be complemented by a policy of mandatory deferred pay, as that may allow for a reduction in the minimum retention requirement.

Our model also yields, next to these normative implications, a number of positive predictions. If gains from securitization are high and the internal agency problem is severe, without regulation, the agent's compensation will be steep, short-term, and based only on loan volume. This should go hand-in-hand with a high level of securitization and low average loan quality and, thus, high subsequent default. The internal agency problem is more severe when it is harder for the bank to control the agent–e.g., given his closeness to the potential borrower or his "soft" information, or when (early) performance indicators of loan quality are less reliable, such as when loans are of longer-term maturity. Instead, if gains from securitization are relatively low and the internal agency problem is less severe, the agent's deferred compensation will be made contingent on loan performance (or the outcome of internal loan reviews) rather than on loan volume. As the agent then screens out bad loans early on, aggregate loan volume will be smaller, but subsequent defaults will become less likely. Below in our main analysis we relate these predictions to the empirical evidence.

Related Literature. In our model, financial institutions can perform an important intermediary service by screening borrowers. But to perform this role, they must provide the respective incentives to their own agents, which is a departure from most papers on intermediation, such as the seminal contributions by Campbell and Kracaw (1980) or Boyd and Prescott (1986), in which a bank also performs an evaluation service. We further analyze how the performance of such intermediation services interacts with the decision to securitize loans. This relates to a recent literature that shows how banks' incentives to closely monitor borrowers can erode through loan sales or hedging (cf. Morrison, 2005;

Parlour and Plantin, 2008; or Parlour and Winton, 2010).[4] In a seminal earlier contribution, Gorton and Pennacchi (1995) show how this incentive problem can be mitigated either by issuing an implicit guarantee against default or by restricting the fraction that is sold.

With regard to the internal agency problem, the banking literature has documented the conflict of interest that arises when agents can exert influence on the loan-approval decision, often based on their private "soft" information (e.g., Udell, 1989). We use a model of a multi-task agency problem, as the agent must exert effort and possibly also reveal private information truthfully. The analysis of a multi-task principal-agent problem follows the seminal contribution of Holmström and Milgrom (1991). More specifically, the interaction of an *ex-ante* moral-hazard problem with a problem of *interim* private information borrows from Dewatripont and Tirole (1999) and Levitt and Snyder (1997), as well as from the literature on "delegated expertise" (e.g., Demski and Sappington, 1987; Lambert, 1986; and, more recently, Gromb and Martimort, 2007, as well as Malcomson, 2009). Inderst and Heider (2010) relate this to banks' choice of lending technology.

Our focus on the time structure of compensation relates to the discussion of how short-terminism in top management compensation affects corporate policy (e.g., Murphy, 2000; Bebchuk et al., 2002). In our model, the bank may fail to choose a compensation scheme that maximizes long-term profits, as it behaves opportunistically with respect to future buyers of its securities. Hence, our model shares with the empirical analysis in Cheng et al. (2009) the view that excessive risk taking, namely through expanding loan volume at the expense of a reduction in quality, is not driven by a governance problem between management and shareholders.[5]

Organization. The rest of this paper is organized as follows. Section 2 introduces the baseline model. We solve for the optimal compensation contract in Section 3. Section 4 characterizes the equilibrium outcome and provides a comparative analysis. Section 5 characterizes the equilibrium when there is mandatory deferred bonus pay and assesses

[4] Chiesa (2008) emphasizes, instead, the positive effect of credit-risk transfer on banks' lending capacity. Benmelech et al. (2010) show empirically when this effect should be less severe. The implications of credit-risk transfer and securitization for systemic risk are analyzed in Allen and Carletti (2006). Duffie (2008) provides an overview of the various ways to transfer credit-risk and the resulting policy issues.

[5] There is also some recent work that analyzes, more generally, the relation between compensation and risk taking in financial institutions, e.g., Balachandran et al. (2010), Bolton et al. (2010b), and Fahlenbrach and Stulz (2010).

the case for a tax on short-term bonuses. Section 6 introduces a policy that prescribes a minimum retention level. We offer some concluding remarks in Section 7.

All proofs are relegated to Appendix A. Appendix B provides some additional results for discussion and robustness, to which we occasionally refer in the main text.

2 Model

Consider an agent who has to originate, process, and potentially close a deal for a financial institution (the principal). To be specific, in what follows, we frame our internal agency problem as a contractual problem between a bank and its loan officer. (See, however, the wider discussion below.) Loans can be of two different types, $\theta \in \{G, B\}$, where *a priori* a loan is of type G with probability $0 < \mu < 1$. The agent must exert effort at cost c to be able to process a loan, which also allows him to learn the loan's quality. In Appendix B, we extend the analysis both to the case where the agent observes only a noisy (continuous) signal about loan quality (Appendix B.4) and to the case where generating such information is costly (Appendix B.1). The agent's information is private and "soft"–i.e., in the language of Berger and Udell (2002), it is "hard to quantify, verify and communicate through the normal transmission channels." As discussed below, our model also extends to the case where the agent can affect the quality of supposedly "hard" information. It is key, however, that the agent can affect the bank's ability to screen borrowers.

Loan-Making and Securitization. A loan requires the up-front capital $\kappa > 0$, which the bank has at its disposal, and yields a repayment of either $R = R_l$ or $R = R_h$, with $R_h > \kappa > R_l \geq 0$. In what follows, we say that the respective borrower defaults when $R = R_l$ is realized.[6] The bank's discount factor is normalized to one. All parties are risk-neutral. A loan of type θ results in a repayment of R_h with probability γ_θ and in a repayment of R_l with probability $1 - \gamma_\theta$. Denote $\eta_\theta := \overline{R}_\theta - \kappa$, where $\overline{R}_\theta := \gamma_\theta R_h + (1 - \gamma_\theta) R_l$ is the loan's expected repayment. We stipulate that $\gamma_G > \gamma_B$, such that $\overline{R}_G > \overline{R}_B$ and, thus, in particular, $\eta_G > \eta_B$. In what follows, it is convenient to refer to $\theta = G$ as a "good loan" and to $\theta = B$ as a "bad loan," though this assessment is based not on the loan's ultimate performance but on the information that is available when the loan is made.

[6]Hence, R_h covers the principal plus the stipulated interest, while R_l is the value of loan recovery.

After a loan is made, the bank securitizes the fraction ψ of the resulting proceeds $\{R_h, R_l\}$, thereby transforming the underlying risky payoff into a sure and immediate cash payment p. The endogenization of p is part of the equilibrium characterization. When this is derived in Section 4, we will also be more explicit about the rationale for securitization. Note, also, that when $R_l > 0$, we presently restrict attention to the case where the bank sells a proportional share ψ of R.

We show in Appendix B that all our results survive when the bank optimally chooses which security, backed by the loan, it wants to issue. Incidentally, in Appendix B.2, we also show that if the bank retains some exposure, then it optimally retains the most risky tranche of a deal (the "equity piece").[7]

Timing. The precise timing in our model is as follows. For simplicity, all actions are taken sequentially in a first period, $t = 1$, while repayments from the loan are realized in period $t = 2$. We now specify the timing in period $t = 1$. At the beginning of $t = 1$, the agent is offered a compensation contract, which we describe below. Immediately afterwards, the agent can exert effort, which is necessary to subsequently process a loan and which allows the agent to learn the loan's quality ("type"). In what follows, we will distinguish between the case where the bank chooses to ignore the agent's information and the case where the bank wants to harness his information to improve the quality of loan-making. At the end of period $t = 1$, when a loan has been undertaken, it may be fully or partially securitized.

Compensation. The agent can be compensated at two points in time: at the end of $t = 2$, after the loan has possibly been repaid, and at the end of $t = 1$, when the bank observes a verifiable but noisy repayment forecast $s \in \{h, l\}$, with $q := \Pr(h|R_h) = \Pr(l|R_l) > 0.5$. The forecast could come from accounting figures or an internal loan review.[8] Deferring compensation is costly, as the agent is more impatient than the bank: He discounts compensation received in $t = 2$ with the factor $0 < \delta < 1$. This assumption

[7] A sale of a fixed portion of loans, albeit possibly backed up by a guarantee against the default of each loan, is considered in Gorton and Pennacchi (1995). Parlour and Plantin (2008) consider the sale of the whole loan.

[8] Note that when $t = 2$ lies "too far" in the future (cf. below, on the agent's time preferences), we can stipulate, instead, that the bank observes at some intermediate period, say $t = 1.5$, another signal. While this is still noisy, it should be more informative than s.

is common in the literatures on labor, executive compensation, and contracting.[9] Note that the agent is also unable to borrow against his future (expected) income, as this would undermine his incentives and, thereby, his future ability to repay such a loan.

As we show below, when the bank does not want to harness the agent's information, it need only compensate the agent for his effort. Without the agent's effort, the bank can not make a new loan. However, when the bank wants the agent to screen loans, it *also* has to ensure that the agent provides this information truthfully. Note that under truthtelling, in our model, this will give the agent effective control over the loan-approval decision.[10] In this case, the two agency problems of exerting effort and of providing information truthfully interact.

Compensation can be made contingent only on, first, whether a loan was made or not and, second, on the repayment realization in $t = 2$ or its forecast in $t = 1$, respectively (cf. Appendix B.1 for a further discussion). Thus, let $\overline{w} \geq 0$ be the agent's base wage when no new loan is made, where we invoke a limited liability constraint. As noted below, $\overline{w}$ will optimally not be deferred. If a loan is made, the agent receives, instead, compensation $w_1(s)$ and $w_2(s, R)$ in the respective periods, conditioning on the early signal s and the final performance of the loan. As at $t = 2$, when R has been realized, the forecast s is no longer informative, we can stipulate that $w_2(s, R) = w_2(R)$. Furthermore, without loss of generality, we can suppose that all compensation that is made in $t = 1$ but that the bank can credibly claw-back later–i.e., that is not "vested"–is postponed until $t = 2$. Together with limited liability, this implies that $w_1(s) \geq 0$ and $w_2(R) \geq 0$.

We will distinguish between the case where the agent is induced only to make loans, but not to use his information to screen out bad loans, and the case where the agent is also induced to screen. We will then be more specific about the shape of the *early* bonus pay

[9] Cf. Rogerson (1997), Ray (2002), or Grenadier and Wang (2005). In the literature, this common assumption is justified on various grounds. For instance, employees may have higher liquidity preferences than the firm does, as they are (more) credit-constrained. In addition, deferred compensation, unless it is securely "ring-fenced," carries the additional risk for the agent that the employer may, through opportunistic behavior, fail to honor his commitment in the future.

[10] It is also straightforward to introduce "hard"–i.e.–verifiable, information. When the bank still wants to rely on the agent's "soft" information, the agent continues to have effective control over the loan-making decision, although compensation will now optimally also depend on "hard" information that is obtained before the loan is approved. When "soft" information is particularly important, as in the case of commercial loans to small- and medium-sized businesses, loan officers may even be given "formal" (instead of only "real") authority over the loan-approval decision, provided that loans satisfy some minimum conditions based on the available hard information (cf. Keys et al., 2010).

$w_1(s)$ and the *deferred* bonus pay $w_2(R)$. To the extent that the bonus does not condition on loan performance–i.e., s or R–we may say that it is contingent only on loan volume. If it conditions on loan performance, so as to induce the agent to screen loans, from limited liability it will be immediate that, $w_1(l) = w_2(R_l) = 0$. For instance, paying zero, $\overline{w}$, or an early bonus could reflect the practice of sharing a year-end bonus pool, based on the performance in the preceding year. Hertzberg et al. (2010) document how compensation for loan officers of a large U.S. bank in Argentina consists of a fixed wage and a year-end bonus. With explicit incentives, as specified in our model, we could also envisage that the bank places a deferred bonus into a separate account, which becomes "vested" only when the respective loans are not in default or, alternatively, when the internal loan review did not reveal negative information.

Altogether, in our model, the bank can decide whether to make compensation contingent only on loan volume or also on loan performance, and whether it wants to defer some or all of it. Casual evidence suggests, at least in the U.S., some variation in the compensation that loan officers receive, with some receiving steeper incentives than others (cf., also, the discussion of our empirical implications in Section 4.3).[11]

Discussion. In our model, we stipulate that the agent can improve the loan-approval decision by screening borrowers based on his privately-observed "soft" information. Alternatively, we could conceive that the agent must be induced not to distort supposedly "hard" information. For instance, the agent could help an applicant for a consumer loan or a mortgage to fake income slips or to otherwise "gamble" the bank's approval process.[12] In general, our model should, thus, be more applicable the more the respective agent can positively *or* negatively affect the quality of the bank's approval decision. This should be

[11] Cf. the following job description of loan officers by the U.S. Department of Labor (http://www.bls.gov/oco/ocos018.htm): "In many instances, loan officers act as salespeople. Commercial loan officers, for example, contact firms to determine their needs for loans. If a firm is seeking new funds, the loan officer will try to persuade the company to obtain the loan from his or her institution. [...] The form of compensation for loan officers varies. Most are paid a commission that is based on the number of loans they originate. In this way, commissions are used to motivate loan officers to bring in more loans. Some institutions pay only salaries, while others pay their loan officers a salary plus a commission or bonus based on the number of loans originated."

[12] Cf., on faking income slips, "FSA bans mortgage brokers for submitting false loan applications," FSA, 21 Feb 2008). There is also anecdotal evidence that to obtain NINA (no income, no asset verification) loans, brokers claimed an income that was high enough for the borrower to obtain a loan (cf. *Washington Post*, "Lies are growing in loan process," 30 Jul 2005, and "Twelfth periodic mortgage fraud report," Mortgage Asset Research Institute, 2010).

more likely when commercial loans are made to small- and medium-sized enterprises, as opposed to large businesses, and in the case of subprime instead of prime mortgages and consumer loans.

Further, while we frame our model in terms of contracting with a bank's loan officer, its insights are more widely applicable, in particular to the compensation of a bank's senior management. As we discuss below in more detail, the bank's main strategy choice will be between making fewer and only good loans or more loans at the expense of a deterioration of average quality. The different business strategies will be associated with different securitization levels, as well as with different compensation contracts. Applying our model more generally, say to the bank's senior management, we may suppose that the respective agent's effort is necessary to expand the bank's business. Whether the agent then ensures that only good-quality ($\theta = G$) "deals" or "deals" of both good and bad quality are undertaken, depends on his compensation contract. The preferences of the bank depend, in turn, on what fraction of the generated risk stays on the bank's books and on what fraction is, instead, off-loaded through securitization.

Organization of the Analysis. In what follows, we first solve the bank's internal agency problem (Section 3). This analysis is then embedded into the bank's overall problem to choose jointly its loan-making, securitization, and compensation strategy (Section 4). Note also that, for now, we abstract from any regulatory interference, which is dealt with in Section 5.

3 Internal Agency Problem

Recall that a loan of type θ results in a high repayment in $t = 2$ with probability γ_θ and, thus, in a high (forecast) signal in $t = 1$ with probability

$$\rho_\theta := q\gamma_\theta + (1-q)(1-\gamma_\theta). \tag{1}$$

Making a loan of type θ, therefore, yields for the agent the expected compensation

$$U_\theta := [\rho_\theta w_1(h) + (1-\rho_\theta)w_1(l)] + \delta[\gamma_\theta w_2(R_h) + (1-\gamma_\theta)w_2(R_l)]. \tag{2}$$

(Recall that the agent discounts compensation received only in $t = 2$ by δ.) We proceed by supposing first that the agent is induced to make only good loans. Subsequently, we consider the case where the agent no longer discriminates between good loans and bad loans. In Section 4, we analyze which of the two cases arises in equilibrium.

The agent will make good loans if

$$U_G \geq \overline{w} \tag{3}$$

and he will refrain from making bad loans if

$$U_B \leq \overline{w}. \tag{4}$$

In addition, the agent's compensation must ensure that he exerts effort as, otherwise, it is not feasible to make a new loan. Provided that conditions (3) and (4) are satisfied, the agent will exert effort if his expected utility from doing so, $\mu U_G + (1-\mu)\overline{w} - c$, does not fall short of his utility from shirking, which is $\overline{w}$. From this, we have the requirement that

$$\mu\left(U_G - \overline{w}\right) \geq c. \tag{5}$$

Since condition (5) implies that the agent strictly prefers to make good loans, we can ignore condition (3). Thus, an optimal compensation scheme that leads to only good loans minimizes the bank's expected wage costs

$$K := \mu\left[\rho_G w_1(h) + (1-\rho_G) w_1(l) + \gamma_G w_2(R_h) + (1-\gamma_G) w_2(R_l)\right] + (1-\mu)\,\overline{w} \tag{6}$$

subject to, first, the incentive constraints (4) and (5) and, second, the limited liability constraints $w_t(\cdot) \geq 0$.

Proposition 1 *Suppose that the bank wants to induce the agent to make only good loans. Then, it always maximally punishes the agent for the bad performance of a loan:* $w_1(l) = w_2(R_l) = 0$. *Further, there exists a cutoff* $0 < \widetilde{\delta} < 1$, *given by*

$$\widetilde{\delta} := \left[1 + \frac{1}{\mu}\left(\frac{1-q}{2q-1}\right)\frac{1}{\gamma_G}\right]^{-1}, \tag{7}$$

such that the agent's optimal compensation is characterized as follows:
i) If $\delta < \widetilde{\delta}$, *the agent receives the base wage*

$$\overline{w} = \frac{c}{\mu}\frac{\rho_B}{\rho_G - \rho_B}, \tag{8}$$

an early incentive component that conditions on the signal s,

$$w_1(h) = \frac{c}{\mu} \frac{1}{\rho_G - \rho_B}, \tag{9}$$

and no deferred compensation: $w_2(R_h) = 0$.

ii) If $\delta > \widetilde{\delta}$, the agent receives the base wage

$$\overline{w} = \frac{c}{\mu} \frac{\gamma_B}{\gamma_G - \gamma_B}, \tag{10}$$

a deferred incentive component that conditions on the ultimate performance of the loan,

$$w_2(R_h) = \frac{c}{\mu} \frac{1}{\gamma_G - \gamma_B} \frac{1}{\delta}, \tag{11}$$

and no early compensation: $w_1(h) = 0$.

iii) If $\delta = \widetilde{\delta}$, either compensation scheme, as characterized in i) and ii), is optimal.

Proof. See Appendix A.

Early Compensation. Now, take case i), where there is no deferred compensation. By making a loan, the agent has the chance to obtain a bonus of $w_1(h)$. Instead, the base wage $\overline{w} > 0$, which the agent could also realize by shirking, represents a sure rent. The agent's expected compensation is, thus, given by $c + \overline{w}$: the sum of the agent's private disutility from exerting effort, for which he has to be compensated, and his rent. We refer to this, after substituting from (8), as

$$K_1 := c + \left(\frac{c}{\mu}\right) \left(\frac{\rho_B}{\rho_G - \rho_B}\right). \tag{12}$$

The agent's rent $\overline{w}$ in (8) is strictly increasing in c/μ, which shows up in the second term in (12). This has the following intuition. When exerting effort is more costly (higher c) or less likely to ultimately result in a loan (lower μ), the agent must be paid a higher bonus. When $w_1(h)$ increases, however, it is necessary to also increase $\overline{w}$. Otherwise, the agent would want to make also bad loans (cf. incentive constraint (4)). Finally, note that the agent's rent decreases when the signal s becomes more informative (higher q).[13]

[13] Formally, note that after substituting from (1) and differentiating, we have

$$\frac{d}{dq}\left(\frac{\rho_B}{\rho_G - \rho_B}\right) = -\frac{1}{(2q-1)^2} \frac{1}{\gamma_G - \gamma_B} < 0.$$

What shapes the form of the optimal compensation scheme and what determines the preceding comparative analysis is the interaction of the two incentive constraints (4) and (5). The agent's effort is necessary for loan-making to be feasible. The compensation that he must receive to cover the respective costs of effort biases the agent towards making even bad loans. To counteract this tendency, the bank must leave the agent with a rent $\overline{w} > 0$. The fact that incentivizing the agent along both "tasks" is costly for the bank is key for all our following results. Arguably, our theory is less applicable when the agent has little scope to generate private "soft" information or to otherwise influence the quality of the loan-approval decision (cf. the discussion in Section 2).

Deferred Compensation. Next, take case ii) in Proposition 1, where compensation is optimally deferred. Intuitively, the rent that is left to the agent, $\overline{w}$, is now strictly lower, given that the bank can condition the bonus on the actual repayment R, which is a more informative signal than the forecast s. On the other hand, deferred compensation creates a "deadweight loss," as the agent is more impatient. Taking this into account, once we substitute for w_2 and $\overline{w}$ from Proposition 1, the expected costs of compensating the agent are now given by

$$K_2 := c + \left(\frac{c}{\mu}\right)\left(\frac{\gamma_B}{\gamma_G - \gamma_B}\right) + c\left(\frac{1-\delta}{\delta}\right)\left(\frac{\gamma_G}{\gamma_G - \gamma_B}\right). \tag{13}$$

The last term in (13) captures the "deadweight loss." This is strictly decreasing in δ and disappears altogether for a perfectly patient agent, as $\delta \to 1$.

For $\delta = \widetilde{\delta}$, the bank is indifferent between early and deferred compensation (case iii in Proposition 1). There, the information gain and the "deadweight loss" ($\delta < 1$) under deferred compensation offset each other exactly. (Formally, the respective expressions (12) and (13) are then just equal: $K_1 = K_2$.) Note, also, that the critical value $\widetilde{\delta}$ in (7) increases in q: When s is more precise (higher q), less information can be gained by waiting for the true performance of the loan, as captured by R. Deferred compensation then becomes less attractive compared to early compensation. In the limit, as $q \to 1$, the information gain vanishes: $\widetilde{\delta} \to 1$.

For future reference, it is convenient to use a short-hand expression for the expected costs of compensation–i.e., the minimum of $K = K_1$ in (12) and $K = K_2$ in (13). As we presently consider the case where only good loans are made, we refer to this as

$$K_G := \min\{K_1, K_2\}.$$

Making Both Good and Bad Loans When loans of either quality are made, the agent needs to be incentivized only to exert effort. The optimal compensation scheme minimizes the bank's expected wage costs. As deferring compensation is costly, the agent is compensated only in $t = 1$: There are no benefits, only costs, from deferred compensation. The agent simply receives an early bonus $w_1 = c$ when a new loan is made, implying also that no rent is paid: $\overline{w} = 0$. Without "deadweight loss" from deferred compensation and without a rent for the agent, the bank's costs of compensation are equal to the agent's costs of effort, c. For ease of reference, we denote these costs by

$$K_{GB} = c.$$

4 Market Outcome

The bank may choose either a compensation scheme that leads to only good loans or one under which both good and bad loans are made. (While the bank might also randomize between the two compensation schemes, we show below that this will never be the case in equilibrium.) Since outsiders do not observe the bank's compensation scheme, the price that a rational investor is willing to pay for a share of the bank's (securitized) loans depends on his beliefs about the bank's chosen compensation scheme. As we will see, the bank's optimal choice of compensation and, thus, the quality of loans depend, in turn, on the price p that it receives for the issued securities. The following equilibrium analysis studies this interaction.

Securitization. Benefits from securitization may arise as the bank has access to some profitable private investment opportunity, which it can not fund otherwise because it is, at least to some extent and in the short run, financially constrained. Alternatively, gains from securitization may arise from risk diversification, either because the bank's owners are not fully diversified or because of costs arising from the threat of bankruptcy or binding regulatory constraints.[14]

[14] For an analysis of the benefits of credit-risk transfer, see Froot and Stein (1998). In Morrison (2005), risk-averse banks buy credit insurance against their loans. Parlour and Plantin (2008) argue that when

While non-financial firms also may choose to securitize future cash flows, either for funding or for risk-management purposes, this is arguably more important for financial firms. As non-financial firms typically borrow against receivables that accrue from their productive securities, their securitization activity is limited by the scope of their real operations (cf., also, ECB, 2007 on the relatively small size of securitization activity by non-financials). For financial firms, however, securitization is more directly linked to credit origination as one of their primary fields of operations (cf., also, Loutskina, 2010; or Martín-Oliver and Saurina, 2007).

We denote by $\tau \geq 0$ the bank's gains from securitization that arise as the market in $t = 1$ has a higher willingness to pay for claims due in $t = 2$.[15] Suppose that the bank makes both good and bad loans and that these are fully securitized at fair value, which is then $(1+\tau)\overline{R}_{GB}$ with $\overline{R}_{GB} := \mu\overline{R}_G + (1-\mu)\,\overline{R}_B$. We stipulate that the expected proceeds exceed the (effort) cost that it takes to originate and close a loan:

$$\tau\overline{R}_{GB} + \mu\eta_G + (1-\mu)\,\eta_B > c. \tag{14}$$

(Recall that $\eta_\theta := \overline{R}_\theta - \kappa$.) Bad loans are assumed to be always loss-making:

$$\eta_B < 0. \tag{15}$$

Conditions (14) and (15) jointly ensure that there is scope for both an equilibrium where the bank makes only good loans and an equilibrium where it makes good and bad loans.[16]

Price of Securities. Investors compete themselves down to zero profits. If they believe that the bank makes only good loans, the securities' price is equal to

$$p_G := (1+\tau)\,\overline{R}_G. \tag{16}$$

If investors believe that the bank makes both good and bad loans, the price is equal to

$$p_{GB} := (1+\tau)\,\overline{R}_{GB}. \tag{17}$$

keeping loans on their balance sheet, banks may be prevented from exploiting private redeployment opportunities, due to either their own insufficient liquidity or binding capital requirements.

[15] Alternatively, albeit with additional notational complications, we could capture different time preferences through a set of discount factors $\delta_A < \delta_B < \delta_M$, where δ_A represents the agent, δ_B represents the bank, and δ_M represents the market. (For convenience, we have set $\delta_B = 1$.)

[16] Instead, when $\eta_B \geq 0$, all loans would always be made and would be fully securitized, while for $\tau\overline{R}_{GB} + \mu\eta_G + (1-\mu)\,\eta_B < c$, there could only be an equilibrium with only good loans.

For a given level of securitization ψ and a given price p, the bank's payoff when only good loans are made equals

$$V_G := \mu \left[\psi \left(p - \overline{R}_G\right) + \eta_G\right] - K_G. \tag{18}$$

Note that this is net of the respective costs of compensation, K_G. The term $\psi \left(p - \overline{R}_G\right)$ in (18) denotes the benefits from securitizing the fraction ψ. When the price is fair, $p = p_G$, these benefits are equal to $\psi\tau\overline{R}_G$. We obtain analogously the bank's payoff when loans of both types are made and when a fraction ψ is sold at price p:

$$V_{GB} := \psi \left(p - \overline{R}_{GB}\right) + \mu\eta_G + (1 - \mu)\, \eta_B - K_{GB}. \tag{19}$$

Analysis. Recall that the securitization decision is made only *after* the bank has chosen a compensation scheme, which gives rise to a game of private information between the bank and outside investors. However, it proves useful to first consider an auxiliary game where the bank can commit to a (maximum) level of securitization *ex-ante*, that is, *before* it chooses its compensation scheme. Then, in a second step, we show that the equilibrium outcome for the auxiliary game is the unique (refined) equilibrium outcome also in the original game.

4.1 Equilibrium Analysis for the "Commitment Game"

Take the level of securitization ψ as given. We solve for the rational-expectations equilibrium when investors correctly anticipate the compensation structure and, thus, average loan quality. When only good loans are made, we have $p = p_G$. Once we substitute this into (18) and (19), we see that the bank, indeed, has an incentive to induce the agent to screen loans when

$$\psi \leq \underline{\psi} := \left(-\eta_B - \frac{\Delta_K}{1-\mu}\right) \frac{1}{p_G - \overline{R}_B}, \tag{20}$$

where

$$\Delta_K := K_G - K_{GB}$$

denotes the *incremental* cost of incentivizing the agent to screen loans. From (20), there exists a maximum level of securitization, $\underline{\psi}$, such that the outcome with only good loans can be supported as long as $\psi \leq \underline{\psi}$.[17]

[17] The threshold $\underline{\psi}$ in (20) can be negative when the additional cost of providing incentives to make only good loans becomes too high. In this case, even if the bank retained 100 per cent of all loans, it would still not induce the agent to make only good loans.

Next, we ask when the bank prefers that both good and bad loans are made, while this is correctly anticipated by the purchasers of its securities: $p = p_{GB}$. From substitution into the bank's payoff in (19), this outcome can be supported for a given level of securitization ψ, when ψ is sufficiently high:

$$\psi \geq \overline{\psi} := \left(-\eta_B - \frac{\Delta_K}{1-\mu} \right) \frac{1}{p_{GB} - \overline{R}_B}. \tag{21}$$

The right-hand side of (21) is strictly smaller than one. Thus, when the level of securitization is too high, the bank will no longer care about the quality of loans. This is intuitive. What will, however, interest us more is whether this case will also arise when ψ is chosen endogenously, and how the outcome depends on the chosen compensation scheme.

As the threshold $\underline{\psi}$ in (20) is strictly smaller than $\overline{\psi}$ in (21), there exists an intermediate range $\psi \in (\underline{\psi}, \overline{\psi})$ for which the bank mixes between inducing the agent to make only good loans or both good and bad loans.

Lemma 1 *Consider the "commitment game," where the bank chooses the level of securitization ψ before it determines the agent's compensation scheme. Then, for given ψ, the unique continuation equilibrium is characterized as follows.*
i) If condition (20) holds, such that $\psi \leq \underline{\psi}$, only good loans are made.
ii) If condition (21) holds, such that $\psi \geq \overline{\psi}$, both good and bad loans are made.
iii) If conditions (20) and (21) both fail, such that $\psi \in (\underline{\psi}, \overline{\psi})$, the bank mixes between inducing the agent to make only good loans and inducing him to make both good and bad loans.

Proof. See Appendix A.

Securitization Decision. As we show, the bank optimally considers only the following two strategies. The first strategy is to fully off-load the risk from new loans, such that $\psi = 1$. We know that this implies that both good and bad loans will be made (as $\overline{\psi} < 1$). The second strategy is to keep ψ sufficiently low so as to (just) credibly commit to incentivize the agent to make only good loans. Note, in particular, that it is not optimal to set $\psi \in [\overline{\psi}, 1)$, as the bank would then still realize only the price p_{GB}. (Further, we show in the proof of Proposition 2 that it is also not optimal to choose $\psi \in (\underline{\psi}, \overline{\psi})$, which would give rise to a mixed-strategy equilibrium.)

We now substitute $\psi = \underline{\psi}$ from (20) together with $p = p_G$ into the respective profits V_G. For V_{GB}, we substitute $\psi = 1$ together with $p = p_{GB}$. Comparing the respective profits V_G and V_{GB}, the bank wants to limit securitization to $\underline{\psi}$, thereby making it credible to induce the agent to screen loans if

$$\tau \overline{R}_{GB} < \left(-\eta_B - \frac{\Delta_K}{1-\mu} \right) \left(1 - \mu \frac{\overline{R}_G - \overline{R}_B}{p_G - \overline{R}_B} \right). \tag{22}$$

Proposition 2 *In the "commitment game," where the bank chooses the level of securitization ψ before it determines the agent's compensation scheme, the equilibrium is characterized as follows. If (22) holds, the bank will securitize loans only up to $\psi = \underline{\psi}$ and induce the agent to make only good loans. If the opposite of (22) holds strictly, then the bank fully securitizes a loan, $\psi = 1$, and induces the agent to make both good and bad loans. When (22) holds with equality, both outcomes can arise.*

Proof. See Appendix A.

Before we discuss in detail the characterization in Proposition 2 and derive predictions from it, we first show in Section 4.2 that Proposition 2 also characterizes the outcome of the original game, where securitization is chosen only after loans have been made.

4.2 Equilibrium in the Original Game

Return to the original game, where the bank chooses ψ only after a loan has been made. Given that outsiders do not observe the bank's choice of compensation, this represents a game of incomplete information. It is well known that by specifying sufficiently "pessimistic" beliefs for any out-of-equilibrium choice of ψ, a wide range of equilibria can be supported in such games.[18] In particular, one can still support the same outcome as in the auxiliary game (cf. Proposition 2). We employ the refinement criterion of Forward Induction (cf. Govindan and Wilson, 2009).[19]

[18] Note, however, that in contrast to a (standard) signaling game, in our model, the "type" of the bank is endogenous. (In fact, in a pure-strategy equilibrium, the market's beliefs about the average quality of loans is degenerate *before* ψ is observed.)

[19] Forward Induction captures the idea that players should, even if they observe something unexpected, assume that other players chose rationally in the past and that they will choose rationally in the future. Consequently, the support of investors' updated beliefs is restricted to such strategies that are an optimal continuation in some Perfect Bayesian Equilibrium. Applied to our setting, investors' beliefs should, thus, put positive probability mass on "GB" after observing an out-of-equilibrium value ψ only if there exists an equilibrium such that $\{"GB", \psi\}$ is a profit-maximizing strategy for the bank.

Proposition 3 *Consider the original game, where ψ is chosen after a loan has been made. When investors believe that any $\psi > \underline{\psi}$ is chosen by a bank that induces the agent to make both good and bad loans, while investors believe that any $\psi \leq \underline{\psi}$ is proposed by a bank that makes only good loans, we can still support, as a Perfect Bayesian Equilibrium, the outcome of the auxiliary game (Proposition 2). Moreover, this is the unique outcome consistent with Forward Induction.*

Proof. See Appendix A.

Naive Investors. Finally, we want to relax the assumption that all investors are equally wary with respect to the quality of securitized loans. Therefore, we suppose that some investors do not adequately take into account the bank's incentives to create more loans at the expense of quality. Closely following Bolton et al. (2010a), we stipulate that such (naive) investors always believe that the bank makes only good loans. While in Bolton et al. (2010a), naive investors do not correctly anticipate the self-interest of rating agencies, in our model, they do not correctly anticipate the bank's self-interest. As suggested in Bolton et al. (2010a), this could also be the case since some investors are managing third-party investments and have insufficient incentives to perform due diligence.

Thus, let α be the probability that a given investor is naive in this way. The expected market price is then[20]

$$\widehat{p} := \alpha p_G + (1-\alpha)\, p,$$

where $p = p_G$ or $p = p_{GB}$, depending on wary investors' rational expectations. Note that when both good and bad loans are made, naive investors underestimate the probability of default: While it is actually given by

$$d_{GB} := \mu(1-\gamma_G) + (1-\mu)(1-\gamma_B),$$

they believe that it is equal to $d_G := 1-\gamma_G$.

The equilibrium is derived following the same steps as above. If only good loans are made in equilibrium, the beliefs of both rational and naive investors are correct. However, when the bank's agent makes both good and bad loans in equilibrium, profits are strictly increasing in α, as naive investors now hold wrong beliefs. To be precise, note that the

[20] Hence, we suppose here, more precisely, that the bank meets a naive buyer of its securities with probability α.

overvaluation of naive investors equals $(1-\mu)\left(\overline{R}_G - \overline{R}_B\right)$, given that a bad loan is now made with probability $1-\mu$, which naive investors do not correctly anticipate. Multiplied by $1+\tau$, to take into account the benefits from securitization, the presence of naive investors thus increases the bank's profits when both good and bad loans are made by

$$\alpha\left(1+\tau\right)\left(1-\mu\right)\left(\overline{R}_G - \overline{R}_B\right).$$

Consequently, condition (22), which determines when only good loans are made in equilibrium, now becomes, more generally,

$$\tau\overline{R}_{GB} + \alpha\left(1+\tau\right)\left(1-\mu\right)\left(\overline{R}_G - \overline{R}_B\right) < \left(-\eta_B - \frac{\Delta_K}{1-\mu}\right)\left(1 - \mu\frac{\overline{R}_G - \overline{R}_B}{p_G - \overline{R}_B}\right). \qquad (23)$$

Hence, we can conclude that, when a given investor is naive with probability α, the bank will securitize only the fraction $\psi = \underline{\psi}$ and induce the agent to make only good loans if condition (23) holds. When the opposite of (23) holds strictly, the bank fully securitizes a loan, $\psi = 1$, and induces the agent to make both good and bad loans. When (23) holds with equality, both outcomes can arise. These observations generalize the characterization in Propositions 2 and 3.

4.3 Comparative Analysis

Proposition 3 reveals that when the bank wants to expand its activities by making both good and bad loans, it optimally steps up securitization ($\psi = 1$). Below, we analyze when, in terms of the model's primitives, this is more likely to be the case. It is first instructive to relate such a switch towards $\psi = 1$ to all other endogenous variables of our model. The following results are implied by Proposition 3, once we substitute condition (23) for the case when $\alpha > 0$ (presence of naive investors).

Corollary 1 *Compare the outcome when the bank induces the agent to screen loans with the outcome when the bank induces the agent to make loans but not to screen. With screening,*

i) compensation also conditions on loan performance, instead of only loan volume, and it is flatter in the sense that $\overline{w} > 0$*, compared to* $\overline{w} = 0$*;*

ii) bonus pay is delayed when $\delta \geq \widetilde{\delta}$*, while otherwise it is never delayed;*

iii) the bank only securitizes a fraction $\underline{\psi} < 1$*, instead of fully securitizing all loans; and* *iv) the average quality of loans is higher and, thus, the likelihood of default lower, $d_G < d_{GB}$, resulting in a higher price p for its securities.*

Agarwal and Wang (2009) analyze data from a field experiment where a piece rate was introduced for a subgroup of a bank's small-business-loan officers. (Note that a piece rate corresponds to the optimal contract without screening.) They find that piece rates result in higher approval rates and a higher rate of default. Assertion iii) makes the additional prediction that loans should be more likely to be (fully) securitized when the respective agents receive steep, volume-oriented, and short-term incentives. There is evidence on the relation between securitization and subsequent default. Purnanandam (2010) shows that originators that made a larger fraction of their loans with the purpose of reselling them in the secondary market experienced higher charge-offs and more defaults when they subsequently were unable to sell once the secondary market had dried up. Dell'Ariccia et al. (2008) relate the expansion in subprime lending to a lowering of lending standards and find that effects are stronger if a larger fraction of the originated loans is sold to outside investors. Mian and Sufi (2009) document how loan denial rates in subprime zip codes decreased when securitization of subprime mortgages went up.

We next ask how securitization, loan quality, and compensation are jointly affected by the model's primitives. Recall that the key condition for this is given by (23). When this holds, only good loans are made in equilibrium; the fraction $\underline{\psi}$ of loans is securitized; the agent receives a strictly positive base wage ($\overline{w} > 0$); and his bonus is possibly deferred (when $\delta \geq \widetilde{\delta}$). For brevity's sake, we simply say that this regime becomes more likely when the respective condition (23) is relaxed. Instead, when a change in primitives has the opposite effect on condition (23), we say that the alternative regime, in which both good- and bad-quality loans are made, becomes more likely.

Corollary 2 *It is more likely that the bank fully securitizes loans and no longer induces the agent to screen, thus providing him with only volume-oriented and short-term incentives, when*

i) the benefits from securitization, τ, are higher;

ii) the probability of finding a naive investor, α, is higher; and

iii) the internal agency problem is more severe. This is the case if the early performance signal is less precise (lower q), if the agent's cost is higher (higher c), or if the agent's time preference is higher (lower δ).

Proof. See Appendix A.

The benefits from securitization should increase when different regulation imposes different financing constraints on the buyers and sellers of these securities.[21] In this vein, Mian and Sufi (2009) find that loans that are sold to non-bank financial firms experience a higher increase in default rates than those that are sold to other banks. (When other investors lack expertise, this may, however, also be consistent with assertion ii).) Keys et al. (2009) compare default rates for mortgages with similar observable characteristics but different likelihood of being subsequently securitized, along assertions iii) and iv) of the preceding Corollary 1. When the originating institution was likely to have a higher funding requirement, the increase in default rate was larger.[22] According to assertion ii), the default rate should also be higher when the bank expects to find investors for its securities that are insufficiently wary, as they lack either sophistication or appropriate incentives to exert due diligence on behalf of their shareholders. Agents originating loans that will likely end up in (packaged) deals targeted at such buyers should, then, receive steep and short-term incentives.

Assertion iii) in Corollary 2 focuses on the bank's internal agency problem. If it becomes harder for the bank to control the agent, the bank is more likely to stop inducing the agent to screen loans. Agarwal and Wang (2009) find that the adverse effect of incentives on loan quality is smaller if the originating agent is more likely to be under closer supervisory scrutiny, as he is younger or shorter-tenured. Jiang et al. (2010) report that a decrease in control over the agent has a higher impact on default rates when the agent is more likely to have private ("soft") information, as a mortgage has only partial instead of full documentation. Finally, Agarwal and Wang (2009) find a greater response of loan quality to more high-powered incentives when loans are of longer maturity, which in our model would imply a higher δ. As we increase the time horizon, τ should also increase, which, from assertion i), works towards strenghtening these predictions.

[21] Several papers, such as Parlour and Plantin (2008), have also suggested an intertemporal shift in τ. They argue that stricter capital requirements, "risk-based" deposit insurance, and the removal of interstate banking restrictions in the Unites States all increased banks' opportunity costs of holding on to their originated loans.

[22] Precisely, as in Keys et al. (2010), this exploits the "rule of thumb" applied by mortgage lenders that a FICO score below 620 makes a borrower "just" unacceptable. The authors argue that loans above the threshold can more easily be securitized.

5 Regulating Compensation

We now analyze the equilibrium outcome in the presence of regulation. In this Section, the only policy that a regulator uses is to impose a requirement to defer any bonus from $t = 1$ to $t = 2$. Subsequently, we analyze the case where a regulator may also control the extent to which loans are securitized.

Consider the constraint that $w_1(\cdot) = 0$. Suppose, first, that the bank does not want to induce the agent to screen loans. In this case, we previously found that the bank always wants to pay out a bonus immediately. When it is, instead, forced to defer the bonus, this must increase to c/δ so as to still induce the agent to exert effort at cost c. Denote the respective compensation costs under regulation by $K_{GB}^R := c/\delta$. When only good loans are made, the respective costs of compensation are $K_G^R := K_2$, which is given in (13).

Recall that we previously characterized the equilibrium without regulation in two steps. We first solved the bank's incentive problem and, thereby, derived the respective costs of compensation K_G and K_{GB}. We then solved jointly for the equilibrium quality of loans and the bank's securitization strategy. With regulation, the only change is that we must now substitute K_G and K_{GB} with the respective costs of compensation K_G^R and K_{GB}^R–or, likewise, Δ_K by the incremental costs of compensation under regulation $\Delta_K^R := K_G^R - K_{GB}^R$. In analogy to (20), the bank will incentivize the agent to make only good loans when

$$\psi \leq \underline{\psi}^R := \left(-\eta_B - \frac{\Delta_K^R}{1-\mu}\right) \frac{1}{p_G - \overline{R}_B}. \tag{24}$$

Next, in analogy to condition (23), we obtain that securitizing only $\psi = \underline{\psi}^R$ is optimal only when

$$\tau \overline{R}_{GB} + \alpha (1+\tau)(1-\mu)\left(\overline{R}_G - \overline{R}_B\right) < \left(-\eta_B - \frac{\Delta_K^R}{1-\mu}\right)\left(1 - \mu \frac{\overline{R}_G - \overline{R}_B}{p_G - \overline{R}_B}\right). \tag{25}$$

Hence, imposing mandatory deferred bonus pay can lead to an increase in the quality of loans only when regulation makes it *relatively cheaper* for the bank to provide the respective incentives:

$$\Delta_K^R < \Delta_K. \tag{26}$$

More formally, when (26) holds, then condition (25) is easier to satisfy than the corresponding condition (23).

Recall that mandatory deferred bonus pay strictly increases the compensation costs when all loans are made indiscriminately: $K_{GB}^R > K_{GB}$. Since for $\delta \geq \widetilde{\delta}$ the optimal compensation for agents who should screen loans already entails deferred compensation, $K_G = K_2$, regulation does not impose additional costs: $K_G^R = K_G$. Hence, we can conclude that for $\delta \geq \widetilde{\delta}$, condition (26) holds strictly. Regulation of pay then increases the likelihood that only high-quality loans are made. However, for $\delta < \widetilde{\delta}$, the converse of (26) may hold, such that regulation can decrease average loan quality.

Proposition 4 *Suppose that deferred bonus compensation is made mandatory. This (weakly) increases average loan quality, thereby reducing the likelihood of default when $\delta > \widehat{\delta}$ holds, where $0 < \widehat{\delta} < \widetilde{\delta}$ is given by*

$$\widehat{\delta} := \left[1 + \frac{1}{\mu}\left(\frac{1-q}{2q-1}\right)\frac{1}{\gamma_B}\right]^{-1}. \tag{27}$$

Instead, for $\delta < \widehat{\delta}$, regulation of pay (weakly) decreases average loan quality. When $\delta = \widehat{\delta}$, regulation has no impact.

Proof. See Appendix A.

We now discuss in detail why policy intervention can lead to a deterioration of loan quality when $\delta < \widehat{\delta}$. At first, this seems somewhat counterintuitive. Recall that the agent must be paid a rent to ensure that he uses his private information to make only good loans. We know that this rent is lower when the bonus is paid in $t = 2$, where the information on loan performance is more precise. However, deferring pay is costly. By forcing the bank to defer the bonus, one could conjecture that the bank becomes more inclined to make use of the information in $t = 2$ and, thereby, to induce the agent to screen loans. This conjecture is, however, not fully true. To see this, recall from our previous discussion that, so as to compensate for the payment of $\overline{w} > 0$, the bank must pay a higher expected bonus when it wants to make only good loans. Crucially, this implies that in this case, also the "deadweight loss" of deferred compensation becomes larger. When $\delta < \widehat{\delta}$, this effect becomes sufficiently strong so that mandatory deferred compensation makes it *relatively* more costly for the bank to ensure that only good loans are made.

Figure 1 illustrates the two cases that are possible from Proposition 4. For concreteness, in addition to varying δ, for this exercise we also vary the benefits from securitization τ. The two hatched areas in Figure 1 capture the regions where regulation strictly affects average loan quality, while in all other areas, loan quality is not affected. In the horizontally

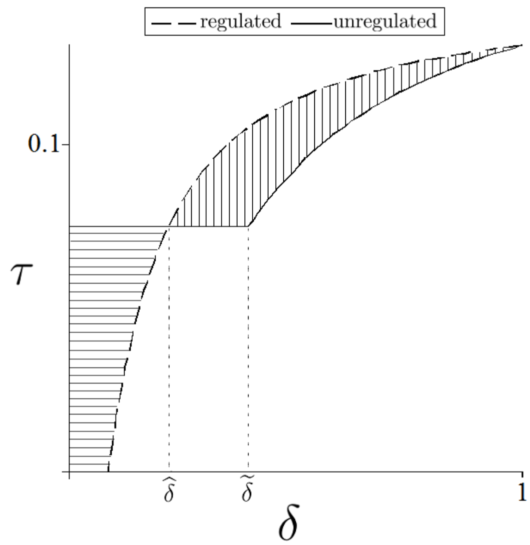

Figure 1: The two curves indicate, as a function of δ, the maximum values for τ such that condition (23) still holds. In the horizontally hatched area, regulation leads to a lower average loan quality and in the vertically hatched area, regulation leads to a higher average loan quality. (Figure 1 is calibrated with the following values: $\mu = 0.7$, $\gamma_G = 0.7$, $\gamma_B = 0.3$, $q = 0.7$, $R_h = 7$, $R_l = 2$, $\kappa = 5$, $c = 0.05$)

hatched area to the left of $\widehat{\delta}$, average loan quality decreases, with a corresponding increase in the likelihood of default from d_G to d_{GB}. In the vertically hatched area to the right of $\widehat{\delta}$, the likelihood of default decreases from d_{GB} to d_G, instead.

The following comparative result follows from differentiation of the threshold $\widehat{\delta}$ in (27).

Corollary 3 *Mandatory deferred bonus pay is more likely to lead to a decrease in the quality of loans when deferring pay imposes high costs (low δ) and generates little additional information on loan performance (high q), or when the average quality of the loan pool is low (low μ).*

Note that, as observed earlier, δ may be lower as, ceteris paribus, the agent is more impatient or as the bank must wait longer to obtain better information about the loan's ultimate performance–e.g., as the maturity of the loan is longer. One could conjecture that the agent's impatience or liquidity preference depends, in particular, on his age and tenure, given that this may affect his own borrowing constraints. For high q and low δ, mandatory deferred pay risks imposing too-high incremental costs of compensation on the bank compared to the derived benefits, in terms of the generated information on loan performance. When the average quality of the loan *pool* deteriorates, the bank must increase its bonus so as to still incentivize the agent. This increase must be higher when the agent is induced to screen loans, as it must also "compensate" the simultaneous increase in $\overline{w}$, which is required to ensure that bad loans are rejected. But then, the increase in the "deadweight loss" is also higher under mandatory deferred pay. Thus, regulation may have unintended consequences precisely when the agent's ability to screen out bad loans is of highest value, as they make up a large fraction of the overall pool.

Does the Bank Benefit from Regulation? Regulating compensation is never in the bank's interest if it destroys the equilibrium with only good loans. Instead, the bank benefits from mandatory deferred pay when it helps to overcome a commitment problem vis-à-vis the buyers of its securities. Mandatory deferred pay is in the bank's interest if, without regulation, it would *not* be credible for the bank to defer pay and, at the same time, relate compensation to loan performance and not only loan volume. However, the bank's and the social planner's (regulator's) preferences are not always perfectly aligned.

Corollary 4 *When $\delta < \widehat{\delta}$, both the bank and the social planner prefer that mandatory deferred pay is not imposed. When $\delta > \widehat{\delta}$, regulating pay may be in the social planner's interest but not in the bank's. Precisely, there exist two thresholds, $\delta_b > \delta_r$, such that regulation is in the social planner's interest if $\delta \geq \delta_r$, while it is in the bank's interest if $\delta \geq \delta_b$.*

Proof. See Appendix A.

The social planner's objective function is the sum of the expected payoff of the bank, of investors, and of the agent. Thus, the rent that the agent obtains when he is induced to screen loans represents, from the social planner's perspective, a pure transfer. Also, when $\alpha > 0$, the bank does not care about the commitment value of regulation vis-à-vis naive investors. These two observations explain the wedge between the social planner's and the bank's preferences in Corollary 4. This gap, $\delta_b - \delta_r$, increases in α (cf. the proof of Corollary 4).

Note, finally, that this gap would widen even further when the subsequent default of loans imposed externalities that are taken into account by the social planner, but not by the bank or the investors in its securities. In Appendix B.3 we consider such an extension.

Bonus Tax. Instead of making it mandatory to defer bonus pay, a regulator may want to affect the bank's incentives by taxing a short-term bonus. Such a tax has been proposed in several countries and, notably, by the International Monetary Fund (IMF, 2010). In our model, the imposition of a percentage tax rate $T < 1$ would firstly affect the agent's payoff in (2):

$$U_\theta := (1-T)\left[\rho_\theta w_1(h) + (1-\rho_\theta) w_1(l)\right] + \delta\left[\gamma_\theta w_2(R_h) + (1-\gamma_\theta) w_2(R_l)\right].$$

Clearly, the bank would then have to compensate the agent through raising his pay. When it does not want to induce the agent to screen out bad loans, the bank either has to pay a short-term bonus of size $c/(1-T)$ or, to avoid the tax, a long-term bonus of size c/δ. When $T > 1-\delta$, the bank defers the bonus. Thus, we have for the cost of compensation $K_{GB}^T = c/(1-T)$ when $T \leq 1-\delta$ and $K_{GB}^T = c/\delta$ when $T > 1-\delta$. When $\delta \geq \widetilde{\delta}$, where $K_G^T = K_2$ holds for any T if the agent is induced to screen, we can conclude that a bonus tax makes the outcome with only good loans more likely. Proposition 5 analyzes also the situation in which a tax has the opposite implication.

Proposition 5 *Suppose that early bonus pay is taxed at rate T. This (weakly) increases average loan quality if $\delta > \widehat{\delta}_T$, where $0 < \widehat{\delta}_T < \widetilde{\delta}$ satisfies*

$$\frac{1-\widehat{\delta}_T}{\widehat{\delta}_T} := \frac{1}{\mu}\left(\frac{1-q}{2q-1}\right)\frac{1}{\gamma_G} + \frac{\gamma_G - \gamma_B}{\gamma_G}\left(\frac{T}{1-T}\right)$$

when $T < 1-\delta$ and $\widehat{\delta}_T = \widehat{\delta}$, as in (27), when $T \geq 1-\delta$. For $\delta < \widehat{\delta}_T$, a bonus tax (weakly) reduces average loan quality. When $\delta = \widehat{\delta}_T$, regulation has no impact on loan quality.

Proof. See Appendix A.

In our model, when the goal of regulation is to induce banks to incentivize their own agents to screen out bad loans, the optimal tax on short-term bonus pay would be as follows. For $\delta \leq \widehat{\delta}$, a tax can only have the opposite effect, such that, optimally, $T = 0$. For $\delta \geq \widetilde{\delta}$, a tax always has the intended consequence, as it affects only "bad" banks. Finally, for $\widehat{\delta} < \delta < \widetilde{\delta}$, the intended consequences are obtained only when the tax is sufficiently large. Thus, in our model, the optimal regime is to either impose no tax or to impose a tax that makes a short-term bonus *in any case* prohibitively expensive: $T \geq 1 - \delta$. This stark characterization is admittedly due to the way we model the agent's preferences, namely by endowing him with risk neutrality together with impatience (liquidity preference). This leaves open the question: Would the additional flexibility of a tax, as compared to making deferred pay mandatory, not be beneficial in another environment?

6 Regulating Securitization

From Proposition 4, mandatory deferred pay can "backfire" by leading to a deterioration of loan quality. A social planner could, however, always "enforce" the desired outcome by requiring the bank to retain at least the fraction $1 - \underline{\psi}$, provided that $\underline{\psi} > 0$. Such a minimum retention requirement was recently imposed in Europe (EC, 2009) and is also being considered in the U.S. (cf. U.S. Treasury, 2009).

In what follows, we will not be concerned with the practical limitations of such a policy. Interestingly, when such a policy is implemented, the imposition of mandatory deferred bonus pay can still play a positive role, provided that $\delta > \widehat{\delta}$. The reason is that by mitigating the bank's commitment problem vis-à-vis investors, regulating compensation reduces the minimum stake that the bank needs to retain. (Formally, we then have that $\underline{\psi}^R > \underline{\psi}$.) In this case, the two policy measures are complementary.

Proposition 6 *Suppose that the social planner could impose mandatory deferred pay or a minimum retention requirement when loans are securitized, or both. When the social planner wants to ensure that bad loans are screened out, this is achieved most efficiently as follows:*
i) If $\delta \leq \widehat{\delta}$, this can be ensured only through imposing a minimum retention requirement $\psi \leq \underline{\psi}$, while imposing mandatory deferred pay would be counterproductive.
ii) There exists $\widehat{\delta} < \overline{\delta} < 1$ such that for $\delta \in (\widehat{\delta}, \overline{\delta})$, it is efficient to still impose only a minimum retention requirement $\psi \leq \underline{\psi}$.
iii) If $\delta \geq \overline{\delta}$, it is efficient to impose mandatory deferred pay together with a minimum retention requirement $\psi \leq \underline{\psi}^R$.

Proof. See Appendix A.

Proposition 6 comes with the caveat that, in our model, the regulator has detailed knowledge about the industry–i.e., about the model's parameters. This allows the regulator to choose a threshold $\underline{\psi}$ or $\underline{\psi}^R$ *precisely,* such that the bank is *just* committed to inducing its agent to make only good loans. Note, also, that when the regulator imposes only a requirement on securitization, without regulating pay, the bank's and the regulator's preferences always diverge if this requirement becomes binding. As we find next, this is no longer the case when the bank faces a commitment problem vis-à-vis investors also with respect to its securitization strategy.

Unobservable Retention. Without regulation it may also not be credible for the bank to commit to retaining a given exposure to the loan, in particular when there is a large, non-transparent market for securitized products or when (single-name) credit derivatives are available in the case of commercial loans.[23] Suppose thus that the bank can no longer commit to retain a minimum fraction of a loan. To capture this, we suppose that there are N possible investors. For simplicity, all investors are wary ($\alpha = 0$). At the securitization stage, the firm can offer each investor a tranche $\widehat{\psi}_n$ with $\sum_{n=1}^{N} \widehat{\psi}_n \leq 1$. Importantly, now each offer is only observed by the respective investor, but not by the other investors.[24] We restrict consideration to symmetric equilibria where $\widehat{\psi}_n = \widehat{\psi}$. Denote thus by $\psi_{nc} = N\widehat{\psi}$ the equilibrium level of securitization under non commitment. We further focus our discussion in the main text on the case where $N \to \infty$, as then, given that $\widehat{\psi} \to 0$, each investor holds, in equilibrium, a negligible fraction of the securitized loan. Intuitively, when the bank then wants to secretly securitize the remaining fraction of a loan, this can be done through targeting a single investor without having a price impact on the securities bought by other investors. Hence, in contrast to a deviation where the total level of securitization is observable to all investors, the bank now gains, in addition, the difference between $\psi_{nc}p_G$ and $\psi_{nc}p_{GB}$. (Recall that $N \to \infty$.)

As formally derived in Proposition 7, in analogy to expression (20) for the threshold $\underline{\psi}$

[23] While our present analysis presumes, for simplicity, that the bank retains, if at all, a fraction of a loan, we can show that a credible commitment to make only good loans would be achieved at the lowest cost through making the bank's remaining exposure as risky as possible (cf. Appendix B, where for $R_l > 0$ the optimal security is derived). In recent years, an active market for such equity tranches has developed with often limited or no transparency on the remaining exposure of the originating bank (cf. Fender and Mitchell, 2009; Franke and Krahnen, 2008).

[24] Adopting a sequential structure for the model would generate the same commitment problem only if it were "open ended."

with observable retention, we now obtain, without observability, the threshold

$$\underline{\psi}_{nc} := \left(-\eta_B - \frac{\Delta_K}{1-\mu} - \frac{\tau \overline{R}_{GB}}{1-\mu} \right) \frac{1}{(1+\tau)\overline{R}_G - \overline{R}_B - \frac{\tau \overline{R}_{GB}}{1-\mu}}. \tag{28}$$

As previously, we now ask when it is profitable for the bank to induce the agent to make only good loans and then securitize only the fraction $\underline{\psi}_{nc}$, instead of making and fully securitizing all loans. Note that, by construction, the choice of $\underline{\psi}_{nc}$ ensures that, at $\psi_{nc} = \underline{\psi}_{nc}$, it just does not pay to deviate by no longer inducing the agent to screen and then "secretly" sell the remaining fraction $1 - \underline{\psi}_{nc}$ at p_{GB}, while still selling the fraction $\underline{\psi}_{nc}$ at p_G. When $\underline{\psi}_{nc} > 0$, it is then *a fortiori* not more profitable to make all loans and securitize *all* of them at p_{GB}.

Proposition 7 *Consider the game where, when a loan is securitized, each investor observes only the size of his tranche, ψ_n, but not the share that the bank retains. We let the number of potential investors go to infinity: $N \to \infty$. Then, taking the limit of the symmetric outcome that is supported by Forward Induction, we have the following:*
i) If $\underline{\psi}_{nc} > 0$, as given in (28), the bank sells the fraction $\underline{\psi}_{nc}$ and induces the agent to make only good loans.
ii) If $\underline{\psi}_{nc} < 0$, all loans are made and then fully securitized ($\psi_{nc} = 1$).
iii) If $\underline{\psi}_{nc} = 0$, both outcomes with $\underline{\psi}_{nc} = 0$ (no securitization) and $\underline{\psi}_{nc} = 1$ (full securitization) can be supported.

Proof. See Appendix A.

As is intuitive, we have that $\underline{\psi}_{nc} < \underline{\psi}$ whenever $\underline{\psi}$ is positive. The "commitment" to make only good loans is more difficult to achieve when the bank's own residual exposure is not observed. As a consequence, without commitment, it is less likely that bad loans will be screened out. (Formally, condition (22) is implied by the new condition $\underline{\psi}_{nc} \geq 0$.)

Regulation with Unobservable Retention. Consider, first, the impact of mandatory deferred bonus pay. Recall from our previous analysis that this affects the equilibrium outcome only through its effect on the compensation cost increment, Δ_K^R instead of Δ_K. As this does not depend on whether or not retention is observable, our previous results fully extend to the case with unobservable retention. Hence, irrespective of whether or not retention is observable, regulating compensation can lead to an increase in the quality of loans only when $\delta > \widehat{\delta}$. Instead, when $\delta \leq \widehat{\delta}$, only a regulation of the bank's securitization activity is effective.

Interestingly, in stark contrast to the case where the bank's retained stake was observable (cf. Proposition 6), the bank may now benefit from the imposition of a minimum retention requirement. This allows the bank to "commit," at lower cost, to inducing the agent to make fewer but better loans. Precisely, the respective cost difference is given by the otherwise foregone benefits from securitization $(\underline{\psi} - \underline{\psi}_{nc})\tau\overline{R}_G$. Incidentally, when without regulation the bank would still want to retain the fraction $1 - \underline{\psi}_{nc}$, the imposition of a minimum retention requirement, $1 - \underline{\psi}$, leads to a *higher* level of securitization. In this case, regulation generates the efficiency gains $(\underline{\psi} - \underline{\psi}_{nc})\tau\overline{R}_G$ even though it does not affect the average quality of loans. As the characterization of the optimal choice between regulating securitization or compensation, or both, is the same as in Proposition 4, we omit a formal proof of the preceding discussion.

7 Conclusion

Our model offers a rationale for why mandatory deferred bonus pay may increase the quality of loans in the presence of securitization, as it helps banks to overcome a commitment problem vis-à-vis the buyers of their securities. At the heart of our argument is the interaction between a bank's *internal agency* problem and its *external agency* problem from securitization. This establishes a link between the compensation structure that the bank provides to its own agents, the quality of its loans, and its securitization strategy.

The ability to securitize creates a commitment problem, which is more severe when the bank can not commit to retain some exposure. While we show that this may be mitigated through mandatory deferred compensation, this can "backfire" and lead, instead, to a deterioration of loan quality. We also analyze the implications of the requirement for banks to retain a minimum exposure to their originated deals. This is only in the bank's own interest when, without such a regulation, the unobservability of the bank's retained exposure creates an additional commitment problem. When deferred compensation is not too inefficient, so that its imposition does not "backfire," mandatory retention and mandatory deferred compensation can become complementary in reducing a bank's opportunism vis-à-vis the investors in its securities. This is the case when regulating compensation reduces the minimum retention required to induce the bank to create the appropriate incentives for its own agents to screen out bad loans.

Banks are more likely to fully securitize a loan, while also making pay more volume-oriented and short-term, when the internal agency problem is more severe, as this implies higher *incremental* costs of inducing agents to screen out bad loans. Further predictions of our model relate to the benefits from securitization and to the sophistication of potential buyers of these securities. Generally, the model predicts how the quality of loans, the level of securitization, and the structure of pay should move together.

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Appendix A Omitted Proofs

Proof of Proposition 1. Note first that by optimality and limited liability, it must hold that $w_1(l) = w_2(R_l) = 0$. Once we substitute and transform the binding incentive constraints (4) and (5)–i.e.,

$$\frac{c}{\mu} = (\rho_G - \rho_B)\, w_1(h) + \delta\,(\gamma_G - \gamma_B)\, w_2(R_h)$$

and

$$w_1(h) = \frac{c}{\mu}\frac{1}{\rho_G - \rho_B} - \delta w_2(R_h)\frac{\gamma_G - \gamma_B}{\rho_G - \rho_B},$$

the expected wage costs K in (6) can be written as

$$K = c + \frac{c}{\mu}\frac{\rho_B}{\rho_G - \rho_B} + \left((1-\delta)\,\mu\gamma_G - \delta\frac{1-q}{2q-1}\right) w_2(R_h).$$

Then, from differentiation, $w_2(R_h) \geq 0$ is optimal when $\delta \geq \widetilde{\delta}$ and $w_1(h) \geq 0$ when $\delta \leq \widetilde{\delta}$. The respective values for $w_1(h)$, $w_2(R_h)$, and $\overline{w}$ then follow immediately from the binding incentive constraints (4) and (5), together with $w_2(R_h) = 0$ in case i) and $w_1(h) = 0$ in case ii). **Q.E.D.**

Proof of Lemma 1. It remains to characterize for the continuation game with given ψ the equilibrium in mixed strategies when $\psi \in (\underline{\psi}, \overline{\psi})$. Denote by λ the probability that the bank will induce the agent to reject bad loans and let $\widehat{\lambda}$ be the investors' expectations about λ. Investors, thus, believe that $\theta = G$ with probability

$$\mu(\widehat{\lambda}) := \frac{\mu}{\widehat{\lambda}\mu + (1 - \widehat{\lambda})},$$

such that their willingness to pay is given by

$$p = (1 + \tau) \left[\mu(\widehat{\lambda}) \overline{R}_G + \left(1 - \mu(\widehat{\lambda})\right) \overline{R}_B \right]. \tag{A.1}$$

Further, using V_G and V_{GB} from (18) and (19), respectively, we find that the bank is indeed indifferent when

$$\psi \overline{R}_B - \eta_B - \frac{\Delta_K}{1 - \mu} = \psi p. \tag{A.2}$$

Once we substitute (A.1) for p and use that $\lambda = \widehat{\lambda}$ ("rational expectations"), we obtain

$$\lambda = \frac{1}{1 - \mu} \left(1 - \mu \frac{\left(\overline{R}_G - \overline{R}_B\right)(1 + \tau)}{\frac{1}{\psi}\left(-\frac{\Delta_K}{1-\mu} - \eta_B\right) - \tau \overline{R}_B} \right). \tag{A.3}$$

Note that indeed $\lambda = 1$ at $\psi = \underline{\psi}$ (provided this is positive), while $\lambda = 0$ at $\psi = \overline{\psi}$. **Q.E.D.**

Proof of Proposition 2. It remains to show that the bank never sets $\psi \in (\underline{\psi}, \overline{\psi})$. Substituting from (A.3) for the resulting equilibrium mixing strategy, the bank's profits are then given by

$$\mu \left[\eta_G - \eta_B - \psi \left(\overline{R}_G - \overline{R}_B \right) \right] - \frac{K_G - \mu K_{GB}}{1 - \mu},$$

which is strictly decreasing in ψ, implying that $\underline{\psi}$ dominates any ψ that induces $\lambda < 1$. **Q.E.D.**

Proof of Proposition 3. The original game with ex-post securitization can be represented more formally as follows. At stage 1, the bank decides on the "quality" $Q \in \{G, GB\}$, where the strategy λ is the probability that $Q = G$ is implemented at cost K_G

instead of $Q = GB$ at cost K_{GB}. At stage 2, a securitization strategy $\sigma(\psi|Q)$ specifies the probability that offer ψ is made, given the actually chosen compensation strategy and the thereby achieved quality of loans Q. At stage 3, investors then buy at the fair price, given their updated beliefs. Investors' beliefs are given by a probability distribution $\mu(\cdot|\psi)$ over $\{G, GB\}$, which is formed according to Bayes' rule when possible–i.e., given the observed ψ and the equilibrium strategies λ^* and $\sigma^*(\cdot)$, it holds that

$$\mu^*(G|\psi) = \frac{\mu\lambda^*\sigma^*(\psi|G)}{\mu\lambda^*\sigma^*(\psi|G) + (1-\lambda^*)\sigma^*(\psi|GB)}.$$

We first support a perfect Bayesian equilibrium that generates the outcome from the auxiliary game of Proposition 2. If condition (23) holds, we specify $\lambda^* = 1$ and $\sigma^*(\underline{\psi}|G) = 1$. If the converse holds strictly, we specify $\lambda^* = 0$ and $\sigma^*(1|GB) = 1$. If the condition holds with equality, we specify $\lambda^* \in [0,1]$ and $\sigma^*(\underline{\psi}|G) = \sigma^*(1|GB) = 1$. For investors we specify the beliefs

$$\mu^*(G|\psi) = \begin{cases} 1 \text{ if } \psi \leq \underline{\psi} \\ 0 \text{ if } \psi > \underline{\psi} \end{cases},$$

implying the price function

$$p^*(\psi) = \begin{cases} p_G \text{ if } \psi \leq \underline{\psi} \\ p_{GB} \text{ if } \psi > \underline{\psi} \end{cases}.$$

We show next that this is also the unique outcome that is consistent with Forward Induction. Take any candidate equilibrium where the bank would, after implementing $Q = G$, choose some $\psi = \widetilde{\psi} < \underline{\psi}$. To support this, after observing $\widehat{\psi} \in (\widetilde{\psi}, \underline{\psi})$, investors must put positive probability on $Q = GB$. However, for $\widehat{\psi} < \underline{\psi}$, the bank would be strictly better off if it had chosen $Q = G$, such that this strategy profile is ruled out by Forward Induction. An analogous argument holds for any "pooling strategy," where $\lambda^* \in (0,1)$ and, subsequently, $\sigma^*(\psi'|G) = \sigma^*(\psi'|GB) = 1$. **Q.E.D.**

Proof of Corollary 2. Note, first, that condition (23) can be rewritten in the following way:

$$\mu\underline{\psi}\tau\overline{R}_G - \Delta_K > \tau\overline{R}_{GB} + (1-\mu)\eta_B + \alpha(1+\tau)(1-\mu)\left(\overline{R}_G - \overline{R}_B\right). \qquad \text{(A.4)}$$

Differentiating the LHS of (A.4) w.r.t. τ yields $\mu\overline{R}_G\underline{\psi} + \mu\tau\overline{R}_G\left(d\underline{\psi}/d\tau\right) < \mu\overline{R}_G$, where we use that

$$\frac{d}{d\tau}\underline{\psi} = \left[\frac{\Delta_K}{1-\mu} + \eta_B\right]\frac{\overline{R}_G}{\left[\overline{R}_G(1+\tau) - \overline{R}_B\right]^2} < 0,$$

while differentiating the RHS w.r.t. τ yields $\mu\overline{R}_G + (1-\mu)\overline{R}_B + \alpha(1-\mu)\left(\overline{R}_G - \overline{R}_B\right) > \mu\overline{R}_G$. This establishes assertion i). Differentiating the LHS of (23) w.r.t. α, we obtain

$$(1+\tau)(1-\mu)\left(\overline{R}_G - \overline{R}_B\right) > 0.$$

Turning to assertion iii), differentiating the RHS of (23) w.r.t. q, we have for $\delta \leq \widetilde{\delta}$

$$\left(\frac{c}{1-\mu}\right)\left(\frac{1}{\mu}\right)\left(\frac{1}{\gamma_G - \gamma_B}\right)\left(\frac{1}{2q-1}\right)^2\left(1 - \mu\frac{\overline{R}_G - \overline{R}_B}{\overline{R}_G(1+\tau) - \overline{R}_B}\right) > 0,$$

while the condition is not affected when $\delta > \widetilde{\delta}$. Next, we differentiate the RHS of (23) w.r.t. c to obtain

$$-\frac{d\Delta_K}{dc}\frac{1}{1-\mu}\left(1 - \mu\frac{\overline{R}_G - \overline{R}_B}{p_G - \overline{R}_B}\right) < 0,$$

where we use that $d\Delta_K/dc > 0$ follows from inspection of K_1 and K_2 in (12) and (13), respectively. Finally, differentiating the RHS of (23) w.r.t. δ yields for $\delta \geq \widetilde{\delta}$

$$\frac{1}{\delta^2}\left(\frac{c}{1-\mu}\right)\left(\frac{\gamma_G}{\gamma_G - \gamma_B}\right)\left(1 - \mu\frac{\overline{R}_G - \overline{R}_B}{\overline{R}_G(1+\tau) - \overline{R}_B}\right) > 0,$$

while the condition is not affected when $\delta < \widetilde{\delta}$. **Q.E.D.**

Proof of Proposition 4. Suppose that deferred bonus compensation is made mandatory, such that $w_1(\cdot) = 0$. As discussed in the main text, we can fully apply the arguments leading to Proposition 2 for the unregulated case, as well as the respective expressions, once we replace Δ_K by Δ_K^R. This yields expression (24) for $\underline{\psi}^R$ and condition (25) for the characterization of the equilibrium with regulation.

Comparing the outcomes with and without regulation, given the argument in the main text, we can restrict consideration to the case where $\delta < \widetilde{\delta}$. The incremental costs $K_G^R - K_G$ are then strictly positive and equal to

$$c\left(\frac{1-\delta}{\delta}\right)\left(\frac{\gamma_G}{\gamma_G - \gamma_B}\right) - \left(\frac{c}{\mu}\right)\left(\frac{1}{\gamma_G - \gamma_B}\right)\left(\frac{1-q}{2q-1}\right).$$

Comparing this to

$$K_{GB}^R - K_{GB} = c\left(\frac{1-\delta}{\delta}\right),$$

we have that (26) holds only if $\delta > \widehat{\delta}$, where $\widehat{\delta}$ is given by (27). Finally, $\widehat{\delta} < \widetilde{\delta}$ follows from inspecting the respective definitions in (27) and (7), while noting that $\gamma_G > \gamma_B$. **Q.E.D.**

Proof of Corollary 4. From the discussion in the main text we can restrict consideration to $\delta > \widehat{\delta}$. Regulation then (weakly) increases the bank's profits when

$$\mu\tau\underline{\psi}^R\overline{R}_G - K_G^R \geq \tau\overline{R}_{GB} + (1+\tau)\,\alpha\left(\overline{R}_G - \overline{R}_{GB}\right) + (1-\mu)\,\eta_B - K_{GB},$$

which, after substitution and rearranging yields the condition

$$\delta \geq \delta_b := \left(1 + \frac{B - C}{A}\right)^{-1}, \tag{A.5}$$

where

$$\begin{aligned}
A &:= c\left[\left(\frac{\gamma_G}{\gamma_G - \gamma_B}\right) + \left(\frac{1}{1-\mu}\right)\left(\frac{\gamma_B}{\gamma_G - \gamma_B}\right)\left(\frac{\mu\tau\overline{R}_G}{\overline{R}_G\,(1+\tau) - \overline{R}_B}\right)\right],\\
B &:= -\tau\overline{R}_{GB} - \eta_B\left(1 - \mu\frac{\overline{R}_G - \overline{R}_B}{\overline{R}_G\,(1+\tau) - \overline{R}_B}\right)\\
&\quad - \left(\frac{c}{\mu}\right)\left(\frac{1}{1-\mu}\right)\left(\frac{\gamma_B}{\gamma_G - \gamma_B}\right)\left(\frac{\mu\tau\overline{R}_G}{\overline{R}_G\,(1+\tau) - \overline{R}_B}\right),\\
C &:= \alpha\,(1+\tau)\left(\overline{R}_G - \overline{R}_{GB}\right) + \left(\frac{c}{\mu}\right)\left(\frac{\gamma_B}{\gamma_G - \gamma_B}\right).
\end{aligned}$$

Likewise, social surplus (weakly) increases when

$$\mu\tau\underline{\psi}^R\overline{R}_G - K_G^R + \frac{c}{\mu}\frac{\gamma_B}{\gamma_G - \gamma_B} \geq \tau\overline{R}_{GB} + (1-\mu)\,\eta_B - K_{GB},$$

which transforms to

$$\delta \geq \delta_r := \left(1 + \frac{B}{A}\right)^{-1}. \tag{A.6}$$

Finally, $\delta_r < \delta_b$ follows from inspecting the respective definitions in (A.5) and (A.6). **Q.E.D.**

Proof of Proposition 5. Suppose, first, that the bank wants to induce the agent to screen out bad loans. The derivation of the optimal compensation is then analogous to Proposition 1, with the only difference that the bank's cost from paying a given after-tax early bonus is now $(1+T)w_1(h)$. This obtains a threshold T_G such that deferred pay is now optimal when $T \geq T_G$, where

$$\frac{T_G}{1 - T_G} := \frac{1}{\rho_G}\left[\frac{1-\delta}{\delta}\,(2q-1)\,\gamma_G - \frac{1}{\mu}\,(1-q)\right].$$

Note that $T_G > 0$ holds only when $\delta < \widetilde{\delta}$. With a bonus tax, we thus have for $T \geq T_G$ that $K_G^T := K_2$, while for $T < T_G$ we have

$$K_G^T := c + \frac{c}{\mu}\frac{\rho_B}{\rho_G - \rho_B} + c\frac{\rho_G}{\rho_G - \rho_B}\frac{T}{1-T}. \tag{A.7}$$

Now recall that $K_{GB}^T := \min\left\{\frac{c}{1-T}, \frac{c}{\delta}\right\}$. Further, to determine the impact of a bonus tax, we have again to determine only the sign of the change in incremental compensation costs, which changes from Δ_K to $\Delta_K^T := K_G^T - K_{GB}^T$. When $T \leq T_G$ and $\delta < \widetilde{\delta}$, we have that

$$\Delta_K^T - \Delta_K = c\frac{\rho_B}{\rho_G - \rho_B}\frac{T}{1-T}.$$

When $T_G < T \leq 1-\delta$ and $\delta < \widetilde{\delta}$, we have that $\Delta_K^T = K_2 - c/(1-T)$, such that $\Delta_K^T - \Delta_K < 0$ only if $\delta > \widehat{\delta}_T$. Finally, when $T \geq 1-\delta$, we have that $\Delta_K^T = K_2 - c/\delta$, which from Proposition 4 is smaller than Δ_K iff $\delta \geq \widehat{\delta}$. **Q.E.D.**

Proof of Proposition 6. Consider first $\delta \leq \widetilde{\delta}$. When only a minimum retention requirement is introduced, total surplus is given by

$$\Omega_r := \mu\tau\underline{\psi}\overline{R}_G + \mu\eta_G - c, \tag{A.8}$$

and if also a mandatory deferred pay rule is introduced, it equals

$$\Omega_c := \mu\tau\underline{\psi}^R\overline{R}_G + \mu\eta_G - c - c\left(\frac{1-\delta}{\delta}\right)\left(\frac{\gamma_G}{\gamma_G - \gamma_B}\right). \tag{A.9}$$

Now, for $\delta \leq \widehat{\delta}$, we know from our prior analysis that $\underline{\psi}^R \leq \underline{\psi}$ and, thus, as then $\Omega_r > \Omega_c$, bonus pay should not be regulated. For $\delta \in (\widehat{\delta}, \widetilde{\delta})$, by contrast, we have that $\underline{\psi}^R > \underline{\psi}$. Comparing (A.8) to (A.9) yields that $\Omega_r \geq \Omega_c$ only if $\delta \geq \overline{\delta}$, which is given by

$$\frac{\overline{\delta}}{1-\overline{\delta}} := \frac{\widehat{\delta}}{1-\widehat{\delta}} + \frac{\overline{R}_G(1+\tau) - \overline{R}_B}{\tau\overline{R}_G}(1-\mu)\gamma_G\left(\frac{2q-1}{1-q}\right).$$

If $\delta \in (\overline{\delta}, \widetilde{\delta})$, therefore, also pay should be regulated. The same is true if $\delta \geq \widetilde{\delta}$. To see this, note that total surplus under only minimum retention then equals

$$\Omega_r := \mu\tau\underline{\psi}\overline{R}_G + \mu\eta_G - c - c\left(\frac{1-\delta}{\delta}\right)\left(\frac{\gamma_G}{\gamma_G - \gamma_B}\right),$$

while if also bonus pay is regulated, total surplus is given by (A.9). The result follows as, for $\delta \geq \widetilde{\delta} > \widehat{\delta}$, we have that $\underline{\psi}^R > \underline{\psi}$ holds strictly. **Q.E.D.**

Proof of Proposition 7. Recall that we restrict attention to the symmetric case. As in Proposition 3, beliefs are a function of the observed offered tranche $\widehat{\psi}_n$. We stipulate again that, conditional on the beliefs, $\mu(\cdot|\psi_n)$, the security is fairly priced. When the bank only makes good loans, then its payoff is

$$V_G := \mu\left(p - \overline{R}_G\right)N\widehat{\psi} + \mu\eta_G - K_G,$$

where in equilibrium $p = p_G$. Suppose that the bank deviates in the following way. It does not induce the agent to screen and securitizes the full loan by selling to $N-1$ investors a total share of $(N-1)\widehat{\psi}$ at $p = p_G$, while selling to one investor the whole residual $1-(N-1)\widehat{\psi}$ at price $p = p_{GB}$. The respective payoff is then

$$V^{dev} := \left(p_G - (1+\tau)\,\overline{R}_{GB}\right)(N-1)\,\widehat{\psi} + \tau\overline{R}_{GB} + \mu\eta_G + (1-\mu)\,\eta_B - K_{GB}, \qquad \text{(A.10)}$$

such that $V_G \geq V_{GB}$ holds only when

$$N\widehat{\psi} \leq \underline{\psi}_{nc}(N) := \frac{-(1-\mu)\,\eta_B - \Delta_K - \tau\overline{R}_{GB}}{(1-\mu)\left[(1+\tau)\,\overline{R}_G - \overline{R}_B\right] - \tau\overline{R}_{GB} - \frac{(1+\tau)(1-\mu)\left(\overline{R}_G - \overline{R}_B\right)}{N}},$$

where $\underline{\psi}_{nc}(N)$ is (when positive) strictly increasing in N with $\underline{\psi}_{nc}(N) \to \underline{\psi}_{nc}$, as given in (28).

We now first support the following (Perfect Bayesian Equilibrium) outcome: i) When $\underline{\psi}_{nc}(N) \geq 0$, the bank induces the agent to make only good loans and then sells to each investor the fraction $\psi_n^* = \underline{\psi}_{nc}(N)/N$; ii) when $\underline{\psi}_{nc}(N) < 0$, the bank induces the agent to make both good and bad loans and then sells to each investor the fraction $\psi_n^* = 1/N$. We stipulate the following beliefs: $\mu\,(G|\psi_n) = 1$ when $\psi_n \leq \underline{\psi}_{nc}(N)/N$ and $\mu\,(GB|\psi_n) = 1$ when $\psi_n > \underline{\psi}_{nc}(N)/N$. To see that this choice supports the equilibrium characterization, note from the discussion in the main text that when $\underline{\psi}_{nc}(N) > 0$, then the bank is strictly worse off by making all loans and then securitizing all of it in a more "transparent" way–i.e., by offering to more than one investor a higher fraction than $\underline{\psi}_{nc}(N)/N$.

It now remains to show that the characterized outcome is uniquely supported by Forward Induction. For brevity, we conduct the argument for the case where beliefs specify either $\mu\,(G|\psi_n) = 1$ or $\mu\,(GB|\psi_n) = 1$, such that in any symmetric equilibrium where $\psi_n^* < 1$ is chosen it must hold, from $\tau > 0$ and from optimality for the bank, that $\mu\,(GB|\psi_n) = 1$ for all $\psi_n > \psi_n^*$, while $\mu\,(G|\psi_n^*) = 1$ when $0 < \psi_n^* < 1$. (The case where $\psi_n^* = 0$ is degenerate, as then there is no sale to investors.) Note also that from the previous discussion it must hold that $\psi_n^* \leq \underline{\psi}_{nc}(N)/N$ when $Q^* = G$. It remains to show that when $\underline{\psi}_{nc}(N)/N > 0$, the unique outcome specifies $Q^* = G$ and $\psi_n^* = \underline{\psi}_{nc}(N)/N$.

Recall that under Forward Induction, when an investor n observes (unexpectedly) $\psi_n \neq \psi_n^*$, he must assume that the bank has chosen its unobserved strategies rationally. In contrast to Proposition 3, this includes now also believes over the vector ψ_{-n}.[25] Take,

[25] See Govindan and Wilson (2009) for a representation. With respect to simultaneous moves, this is

thus, a deviation $\psi_n^* < \psi_n < \underline{\psi}_{nc}(N)/N$. We argue that in anticipation of this move, the bank is strictly better off with $Q = G$ than with $Q = GB$. For this note that the maximum payoff that the bank could realize with $Q = GB$ is obtained as follows. We know that in the candidate equilibrium, it must hold that $\mu\left(GB|\psi_n\right) = 1$ for all $\psi_n > \psi_n^*$. Hence, the bank would then optimally either choose $\psi_{n'} = \psi_n^*$ (and earn p_G) for all $n' \neq n$ or, instead, $\psi_{n'} = 1 - (N-2)\psi_n^* - \psi_n$ for only one n' (and earn p_{GB} on this fraction). However, by construction of $\underline{\psi}_{nc}(N)/N$ the bank's payoff from either choice is strictly inferior to that of choosing $\psi_{n'} = \psi_n^*$ *and* $Q = G$. **Q.E.D.**

then similar in spirit to the use of "wary beliefs" in the Industrial Organization literature (e.g., McAfee and Schwartz 1994).

Appendix B Additional Material

B.1 Discussion of the Agency Problem

In the main text, we stipulated that through generating and dealing with a (potential) loan application, which comes at cost $c > 0$, the agent also learns the type θ and, thus, the probability of subsequent default. When the agent is supposed to use this information so as to prevent making type-B loans, in our model truthtelling (first task) and effort in the loan-making process (second task) become conflicting tasks, making it necessary for the bank to pay the agent a rent when it wants to provide incentives along both tasks. Recall that these tasks can *not* be remunerated separately. In particular, in case the agent reports $\theta = B$, then it is effectively never "tested" whether the agent spent effort to generate a *viable* loan-making opportunity. In a model of static contracting only, where the issue of deferring compensation does not arise, Inderst and Heider (2010) provide various arguments why this specification is realistic and they also discuss how it can be endogenized. Here, we show, instead, how our results also extend to the case where the agent must exert unobservable effort at cost $c_I > 0$ to generate information, while now loan-making opportunities arise exogenously.

Clearly, the bank will then only incentivize the agent to exert effort to generate information when it also provides incentives to use this information to screen out type-B loans. To characterize the optimal compensation in this case, note first that the set of verifiable states is the same as in the main text, so that we can still restrict attention to $\overline{w}$ when no loan was made as well as $w_1(s)$ and $w_2(R)$. Using the same notation as previously, to make sure that the agent, once he is informed, prefers to make only good loans, it must hold that

$$U_G \geq \overline{w} \tag{B.1}$$

and

$$U_B \leq \overline{w}. \tag{B.2}$$

When (B.1) and (B.2) hold, in order to induce the agent to acquire information, two conditions must hold. First, the agent's expected payoff if he becomes informed and screens out bad loans has to exceed his payoff if he remains uninformed and rejects all loans:

$$\mu U_G + (1-\mu)\,\overline{w} - c_I \geq \overline{w}. \tag{B.3}$$

Second, it must also exceed his payoff when he remains uninformed and accepts all loans:

$$\mu U_G + (1-\mu)\,\overline{w} - c_I \geq \mu U_G + (1-\mu)\,U_B. \tag{B.4}$$

To simplify the problem note, first, that (B.3) implies (B.1). In fact, if (B.1) was violated, the agent would prefer to reject all loans even when he knows their type. But then (B.3) would be violated as well. Similarly, if (B.2) did not hold, the agent would prefer to make also type-B loans, implying that it would not pay to exert effort to generate information, such that (B.4) would be violated. Consequently, (B.4) implies (B.2). The bank's problem then reduces to that of minimizing expected wage costs subject to the two incentive constraints (B.3) and (B.4), next to limited liability.

Proposition B.1 *Take the model where the agent must exert unobservable effort to learn about the quality of a potential loan. We characterize the optimal compensation that induces the agent to acquire information and to screen out bad loans. There exists a critical cut off* $0 < \widetilde{\delta} < 1$*, as given by (7) in Proposition 1, such that, next to* $w_1(l) = w_2(R_l) = 0$*, the following holds:*
i) If $\delta < \widetilde{\delta}$*, the agent receives a base wage of*

$$\overline{w} = \frac{1}{\mu(1-\mu)} \frac{\mu\rho_G + (1-\mu)\,\rho_B}{\rho_G - \rho_B} c_I,$$

an early incentive component of

$$w_1(h) = \frac{1}{\mu(1-\mu)} \frac{1}{\rho_G - \rho_B} c_I,$$

and no deferred compensation: $w_2(R_h) = 0$*.*
ii) If $\delta > \widetilde{\delta}$*, the agent receives a base wage of*

$$\overline{w} = \frac{1}{\mu(1-\mu)} \frac{\mu\gamma_G + (1-\mu)\,\gamma_B}{\gamma_G - \gamma_B} c_I,$$

a deferred incentive component of

$$w_2(R_h) = \frac{1}{\mu(1-\mu)} \frac{1}{\gamma_G - \gamma_B} \frac{1}{\delta} c_I,$$

and no early compensation: $w_1(h) = 0$*.*
iii) If $\delta = \widetilde{\delta}$*, either compensation scheme, as characterized in i) and ii), is optimal.*

Proof. We first formalize the steps from the main text that lead to the simplification of the bank's problem. For this note first that the binding incentive constraint (B.3) can be rewritten as $U_G - \overline{w} = \frac{1}{\mu} c_I$ and thus indeed implies (B.1). Next, the binding constraint (B.4) can be rewritten as

$$\overline{w} - U_B = \frac{1}{1-\mu} c_I$$

and thus indeed implies (B.2). By optimality it follows that the two remaining incentive constraints (B.3) and (B.4) must bind. Note that, together with limited liability, this implies $w_1(l) = w_2(R_l) = 0$. Next, the respective expressions for $w_1(h)$ ($w_2(R_h)$, respectively) and $\overline{w}$ follow from substitution, once we set $w_2(R_h) = 0$ ($w_1(h) = 0$, respectively). Finally, the critical cut off $\widetilde{\delta}$ is obtained by comparing

$$K_1 := c_I + \left[\left(\frac{1}{\mu (1-\mu)} \right) \left(\frac{\mu \rho_G + (1-\mu) \rho_B}{\rho_G - \rho_B} \right) c_I \right]$$

with

$$\begin{aligned} K_2 \quad : \quad &= c_I + \left[\left(\frac{1}{\mu (1-\mu)} \right) \left(\frac{\mu \gamma_G + (1-\mu) \gamma_B}{\gamma_G - \gamma_B} \right) c_I \right] \\ &+ \mu \gamma_G \left(\frac{1}{\mu (1-\mu)} \right) \left(\frac{1}{\gamma_G - \gamma_B} \right) \left(\frac{1-\delta}{\delta} \right) c_I . \end{aligned}$$

Q.E.D.

Imposing mandatory deferred pay still increases the bank's cost of inducing information acquisition and making only good loans when $\delta < \widetilde{\delta}$. When the agent's effort is only needed to generate information, then the bank optimally pays a *zero* wage when it no longer wants the agent to screen out bad loans (as it plans to fully securitize loans). As mandatory deferred pay then imposes no additional costs, we have that $\widehat{\delta} = \widetilde{\delta}$, such that regulating pay would *never* have a positive effect on the quality of loans. More realistically, however, even when the agent is not paid to screen out bad loans, he must be compensated for the effort that it takes to originate and process a loan. To distinguish the analysis from that in the main text, we suppose that this is observable and denote the respective costs by $c_L > 0$. When the bank wants to induce the agent to make loans, but not to screen them, mandatory deferred compensation imposes the incremental costs $(1-\delta)c_L/\delta$. After extending the characterization in Proposition B.1 by introducing the additional, observable effort at cost c_L, we see that while $\widetilde{\delta}$ remains unchanged, the cutoff $0 < \widehat{\delta} < \widetilde{\delta}$ now satisfies[26]

$$\widehat{\delta} = \left[1 + \frac{1}{\mu}\frac{1-q}{2q-1}\frac{1}{\gamma_G - (1-\mu)\frac{c_D}{c_I}(\gamma_G - \gamma_B)}\right]^{-1}. \tag{B.5}$$

Recall, finally, that for the equilibrium implications of regulation, we only use the change in incremental costs–i.e., from Δ_K to Δ_K^R and that $\Delta_K^R < \Delta_K$ when $\delta < \widehat{\delta}$ and $\Delta_K^R > \Delta_K$ when $\delta < \widehat{\delta}$.

B.2 Security Design

When $R_l > 0$, suppose now that a security that the bank sells at a price p can stipulate the contingent payoffs $0 \leq S_l \leq R_l$ and $0 \leq S_h \leq R_h$. As is standard, we assume that the payout is monotonic with $S_h \geq S_l$. We first ask how the bank would now *optimally* "commit," say in the auxiliary game where securities are designed before loans are made. Then, the bank realizes the price $p = p_G$ with $p_G := (1+\tau)\overline{S}_G$ and $\overline{S}_G := \gamma_G S_h + (1-\gamma_G) S_l$. To support this outcome, the bank's profits

$$V_G := \mu\left[p - \overline{S}_G + \eta_G\right] - K_G \tag{B.6}$$

must exceed those from secretly deviating by inducing the agent to make all loans:

$$V_{GB} := p - \mu\overline{S}_G - (1-\mu)\overline{S}_B + \mu\eta_G + (1-\mu)\eta_B - K_{GB}. \tag{B.7}$$

Substituting $p = p_G$ into (B.6) and (B.7), this is incentive compatible if

$$-\eta_B - \frac{\Delta_K}{1-\mu} > \tau\overline{S}_G + (\gamma_G - \gamma_B)(S_h - S_l). \tag{B.8}$$

The term $(\gamma_G - \gamma_B)(S_h - S_l)$ represents the "overpayment" by investors if the bank deviates and issues a security that is, contrary to the investors' expectations, backed by a bad loan. If the bank wants to commit, the optimal security (S_l, S_h) maximizes V_G subject to the bank's incentive-compatibility constraint (B.8).

Proposition B.2 *Suppose that the bank wants to commit vis-à-vis investors that it incentivize the agent to conduct only good loans and can, for this purpose, design a security (S_l, S_h). Then, the bank keeps the most risky tranche, as either $S_h = S_l \leq R_l$ or $S_h > S_l = R_l$.*

[26]Strictly speaking, this characterization applies only when $c_L \leq \frac{1}{\mu(1-\mu)}\frac{\mu\gamma_G+(1-\mu)\gamma_B}{\gamma_G-\gamma_B}c_I$.

Proof. We have to distinguish between two cases. If

$$\frac{1}{\tau}\left(-\eta_B - \frac{\Delta_K}{1-\mu}\right) \geq R_l, \tag{B.9}$$

incentive compatibility can be achieved while securitizing the whole "safe" part: $S_l = R_l$. From the by optimality ($\tau > 0$) binding constraint (B.8), it then follows that

$$S_h = S_l + \left(-\eta_B - \frac{\Delta_K}{1-\mu} - \tau R_l\right) \frac{1}{(1+\tau)\gamma_G - \gamma_B}.$$

If condition (B.9) fails, incentive compatibility can only be achieved with $S := S_h = S_l < R_l$. From the binding incentive constraint we then obtain

$$S = \frac{1}{\tau}\left(-\eta_B - \frac{\Delta_K}{1-\mu}\right).$$

Q.E.D.

The intuition for Proposition B.2 is the following. Given the gains from securitization ($\tau > 0$), the bank's objective is to make the sold tranche as valuable as possible–i.e., to maximize p, subject to the incentive constraint (B.8). This is the case when the bank commits to retain the most risky tranche, as this is most affected by a change in the quality of loans. While this is similar in spirit to the insights obtained when securities are optimally designed under ex-ante or interim private information, as in DeMarzo and Duffie (1999), Nachman and Noe (1994), or Myers and Majluf (1984), there is an interesting difference. In our case, it may not be feasible to secure all of the riskless repayment, R_l, such that $S_l = S_h < R_l$. Greater securitization of even the riskless part of the loan increases the bank's payoff from *any* loan that it makes and, thus, also increases its incentives to induce the agent to no longer screen out bad loans.

Additional references for security design:

DeMarzo, P.M., Duffie, D., 1999, A liquidity-based model of security design, Econometrica 67, 65-99.

Myers, S.C., Majluf, N.S., 1984, Corporate financing and investment decisions when firms have information that investors do not have, Journal of Financial Economics 13, 187-221.

Nachman, D.C., Noe, T.H., 1994, Optimal design of securities under asymmetric information, Review of Financial Studies 7, 1-44.

B.3 Externalities

For the purpose of this Section only, suppose that the bank does not securitize its loans: $\psi = 0$. The novelty in this Section is, however, that loan default imposes an exogenous negative externality of size $z > 0$. While it enters the objective function of a regulator or supervisor, it does not enter into the bank's profit function. We suppose that

$$\tau\overline{R}_G + \eta_G - (1-\gamma_G)\, z > 0 > \tau\overline{R}_{GB} + \mu\eta_G + (1-\mu)\,\eta_B - [1 - \mu\gamma_G - (1-\mu)\,\gamma_B]\, z, \quad \text{(B.10)}$$

such that from the perspective of social welfare it still holds that only good loans should be undertaken. It is easily established from our previous results (notably, expressions (18) and (19)), that without regulation, the bank finds it optimal to incentivize its agents to undertake only good loans if

$$-(1-\mu)\,\eta_B \geq \Delta_K. \quad \text{(B.11)}$$

Clearly, if the converse of condition (B.11) holds strictly, the bank prefers to make all loans, although this is, from (B.10), socially inefficient. In particular, from $\Delta_K > 0$, the bank may still prefer to undertake all loans indiscriminately, even though bad loans are of negative NPV and, thus, both privately and socially inefficient.[27] If (B.11) holds strictly, private and social objectives coincide: Only good loans will be made in equilibrium.

Because (B.11) depends on the cost differential Δ_K in the same way as previously, our insights on the implications of mandatory deferred pay carry over to this extension.

Proposition B.3 *Take the modified model where there is no securitization, but where loan default results in negative externalities, such that (B.10) holds. Then, imposing deferred bonus compensation (weakly) increases the risk of default when $\delta < \widehat{\delta}$, in which case both the bank and the social planner would prefer not to impose regulation. In contrast, for $\delta > \widehat{\delta}$, regulating compensation (weakly) reduces the risk of default, which may be in the social planner's interest but not in that of the bank. Precisely, there exist two thresholds $\delta_{Eb} > \delta_{Er}$ such that regulation is in the social planner's interest if $\delta \geq \delta_{Er}$, and it is in the bank's interest if $\delta \geq \delta_{Eb}$*

[27] For brevity's sake, we abstract for now from the fact that the "dead-weight loss" from deferred compensation also enters the social welfare function. This does, however, not affect the result that the bank has too-high incentives to also undertake bad deals.

Proof. It remains to consider the case with $\delta > \widehat{\delta}$. When regulating compensation improves the quality of loans, this increases bank profits when

$$\mu\tau\underline{\psi}^R\overline{R}_G - K_G^R > \tau\overline{R}_{GB} + (1-\mu)\,\eta_B - K_{GB},$$

which, after substitution and rearranging yields

$$\delta \geq \delta_{Eb} := \left(1 + \frac{B}{A}\right)^{-1},$$

where

$$\begin{aligned}
A \ &: = c\left[\left(\frac{\gamma_G}{\gamma_G - \gamma_B}\right) + \left(\frac{1}{1-\mu}\right)\left(\frac{\gamma_B}{\gamma_G - \gamma_B}\right)\left(\frac{\mu\tau\overline{R}_G}{\overline{R}_G\,(1+\tau) - \overline{R}_B}\right)\right],\\
B \ &: = -\tau\overline{R}_{GB} - \eta_B\left(1 - \mu\frac{\overline{R}_G - \overline{R}_B}{\overline{R}_G\,(1+\tau) - \overline{R}_B}\right) - \left(\frac{c}{\mu}\right)\left(\frac{\gamma_B}{\gamma_G - \gamma_B}\right)\\
&\quad - \left(\frac{c}{\mu}\right)\left(\frac{1}{1-\mu}\right)\left(\frac{\gamma_B}{\gamma_G - \gamma_B}\right)\left(\frac{\mu\tau\overline{R}_G}{\overline{R}_G\,(1+\tau) - \overline{R}_B}\right),\\
C \ &: = (1-\mu)\,(1-\gamma_B)\,z + \left(\frac{c}{\mu}\right)\left(\frac{\gamma_B}{\gamma_G - \gamma_B}\right).
\end{aligned}$$

Likewise, regulation is then in the social planner's interest if

$$\mu\tau\underline{\psi}^R\overline{R}_G - K_G^R + \frac{c}{\mu}\frac{\gamma_B}{\gamma_G - \gamma_B} > \tau\overline{R}_{GB} + (1-\mu)\,\eta_B - (1-\mu)\,(1-\gamma_B)\,z,$$

which, using the same notation as above, becomes

$$\delta \geq \delta_{Er} := \left(1 + \frac{B+C}{A}\right)^{-1} < \delta_{Eb}.$$

Q.E.D.

B.4 Noisy Information

We extend our analysis to the case where the agent's information about the quality of a loan in $t = 1$ is noisy. Let $\mu := \Pr(\theta = G)$ be the agent's posterior belief after privately receiving additional information. From an ex-ante perspective, $\mu \in [0,1]$ is distributed according to some CDF, $F(\mu)$, with the common prior satisfying $\overline{\mu} := \int \mu dF(\mu)$.

Internal Agency Problem. Conditional on his posterior, μ, closing a loan yields the agent an expected utility of

$$u(\mu) := \mu U_G + (1-\mu)U_B.$$

Note that as long as $\min\{w_1, w_2\} > 0$, the agent's payoff u is strictly increasing in μ. The critical threshold where the agent is indifferent between closing a loan and rejecting it, μ^*, if interior, satisfies

$$u(\mu^*) = \overline{w}. \tag{B.12}$$

The agent will exert effort if the wedge between his bonus and his base wage is sufficiently large–i.e., if

$$\int_{\mu^*}^{1} (u(\mu) - \overline{w}) dF \geq c. \tag{B.13}$$

Denote by

$$\gamma(\mu) := \mu\gamma_G + (1-\mu)\gamma_B$$

the probability of non-default.

Proposition B.4 *Suppose that the bank wants to implement a minimum loan quality μ^*, such that the agent only makes a loan when his posterior satisfies $\mu \geq \mu^*$. Then, there exists a critical threshold, $\widetilde{\delta}$, given by*

$$\frac{\widetilde{\delta}}{1-\widetilde{\delta}} := \left(\frac{2q-1}{1-q}\right) \int_{\mu^*}^{1} \gamma(\mu)\, dF, \tag{B.14}$$

such that, next to $w_1(l) = w_2(R_l) = 0$, the agent's optimal compensation is characterized as follows:

i) If $\delta < \widetilde{\delta}$, the agent receives an early bonus of

$$w_1(h) = \frac{c}{\int_{\mu^*}^{1} (\mu - \mu^*) dF} \left(\frac{1}{\rho_G - \rho_B}\right),$$

a base wage of

$$\overline{w} = \frac{c}{\int_{\mu^*}^{1} (\mu - \mu^*) dF} \left(\mu^* + \frac{\rho_B}{\rho_G - \rho_B}\right),$$

and no deferred bonus as $w_2(R_h) = 0$. The respective costs of compensation equal

$$K_1 = c + c\frac{1}{\int_{\mu^*}^{1} (\mu - \mu^*) dF} \frac{1}{\gamma_G - \gamma_B} \left[\gamma(\mu^*) + \frac{1-q}{2q-1}\right] \tag{B.15}$$

ii) If $\delta > \widetilde{\delta}$, the agent receives a deferred bonus of

$$w_2(R_h) = \frac{c}{\int_{\mu^*}^{1} (\mu - \mu^*) dF} \left(\frac{1}{\gamma_G - \gamma_B}\right) \frac{1}{\delta},$$

a base wage of

$$\overline{w} = \frac{c}{\int_{\mu^*}^1 (\mu - \mu^*) dF} \left(\mu^* + \frac{\gamma_B}{\gamma_G - \gamma_B} \right),$$

and no early bonus as $w_1(h) = 0$. *The respective costs of compensation equal*

$$K_2 = c + c \frac{1}{\int_{\mu^*}^1 (\mu - \mu^*) dF} \frac{1}{\gamma_G - \gamma_B} \left[\gamma(\mu^*) + \frac{1-\delta}{\delta} \int_{\mu^*}^1 \gamma(\mu) dF \right]. \qquad \text{(B.16)}$$

iii) If $\delta = \widetilde{\delta}$, *either compensation scheme, as characterized in i) and ii), is optimal.*

Proof. When setting $w_2(R_l) = 0$, next to $w_1(l) = w_2(R_l) = 0$, we have $U_\theta = \rho_\theta w_1$ which, by (B.12) and (B.13) yields the respective compensation scheme. The bank's costs of compensation are given by

$$K_1 := \int_0^{\mu^*} \overline{w} dF + \int_{\mu^*}^1 u(\mu) dF$$

which, using (B.13), is equal to $c + \overline{w}$ and, thus, yields (B.15). Next, for $w_1(l) = 0$, we have $U_\theta = \delta \rho_\theta w_2$. Once we substitute this into (B.12) and (B.13), we obtain the respective optimal deferred compensation. Costs of compensation are equal to

$$K_2 := \int_0^{\mu^*} u(\mu^*) dF + \frac{1}{\delta} \int_{\mu^*}^1 u(\mu) dF,$$

or, after substituting and rearranging, (B.16). Finally, from comparing K_1 with K_2, we obtain the threshold $\widetilde{\delta}$ in (B.14). **Q.E.D.**

While under early compensation the agent has to be paid a higher rent $\overline{w}$ (cf. the last term in (B.15)), deferred compensation induces a "deadweight loss" (cf. the last term in (B.16)). Observe now that the critical threshold $\widetilde{\delta}$ as given in (B.14), is strictly decreasing in μ^*. Thus, it is more likely that the agent will optimally receive a deferred bonus if the bank wants to implement a higher minimum quality, μ^*. This generalizes our previous observations. In the following, we denote the costs of compensation–i.e., the minimum of K_1 and K_2 for given μ^*, by

$$K(\mu^*) := \min\{K_1, K_2\}.$$

Market Outcome. When investors expect the bank to implement a minimum quality of $\widehat{\mu}^*$, their willingness to pay is given by

$$p(\widehat{\mu}^*) := (1+\tau)\int_{\widehat{\mu}^*}^{1} \overline{R}(\mu)\frac{dF}{1-F(\widehat{\mu}^*)}, \tag{B.17}$$

where

$$\overline{R}(\mu) := \mu\overline{R}_G + (1-\mu)\overline{R}_B$$

is the expected repayment of a loan conditional on μ. Note that $p(\cdot)$ is strictly increasing in $\widehat{\mu}^*$. Further, for *given* price p and ψ the bank's expected profits are equal to

$$\int_{\mu^*}^{1} \left[\eta(\mu) - \psi\overline{R}(\mu) + \psi p\right] dF - K(\mu^*). \tag{B.18}$$

An interior solution μ^* that maximizes (B.18) must then satisfy the first-order condition[28]

$$-f(\mu^*)\left[\eta(\mu^*) - \psi\overline{R}(\mu^*) + \psi p\right] = K'(\mu^*). \tag{B.19}$$

In what follows, we restrict consideration to the case where the bank's program is strictly quasiconcave and always obtains an interior solution. (Note that from the definition of $K(\cdot)$ there will be generally a kink in the compensation cost function.) Then, it follows directly from implicit differentiation of (B.19) that the optimal minimum quality, $\mu^*(p)$, is strictly decreasing in p, which is intuitive. A rational expectations equilibrium is pinned down by the requirement that $p = p(\widehat{\mu}^*)$ holds under the anticipated minimum quality, while the anticipated minimum quality is indeed optimal for the bank as $\mu^*(p) = \widehat{\mu}^*$. (Note that we consider again the auxiliary game where ψ is chosen first.) Since $p(\widehat{\mu}^*)$ is strictly increasing in $\widehat{\mu}^*$ and $\mu^*(p)$ is strictly decreasing in p, if the system $p = p(\widehat{\mu}^*)$ and $\mu^* = \mu^*(p)$ has a fixed point with an interior solution $0 < \mu^* < 1$, then this must be unique.

To characterize an equilibrium for the full game, where ψ is endogenous, and to then analyze the impact of regulation, we first need to characterize how a change in securitization affects the outcome of the continuation game and, thus, μ^*. We now restrict consideration to the case where μ is uniformly distributed:

$$f(\mu) = 1 \text{ for all } \mu \in [0,1].$$

[28]Note that, while the optimal μ^* is a function of all variables, we will write $\mu^*(p)$ in order to stress that it is a function of the securities' price.

Substituting $f(\mu) = 1$ into (B.17) and (B.19), together with the equilibrium requirement that $\widehat{\mu}^* = \mu^*$, we have from total differentiation

$$\begin{pmatrix} -\left[\overline{R}'(\mu^*)(1-\psi) + K''(\mu^*)\right] & -\psi \\ -\left[(1+\tau)\overline{R}(\mu^*) - p\right] & -(1-\mu^*) \end{pmatrix} \begin{pmatrix} d\mu^* \\ dp \end{pmatrix} = d\psi \begin{pmatrix} p - \overline{R}(\mu^*) \\ 0 \end{pmatrix}$$

and, thus, from Cramer's rule

$$\frac{d\mu^*}{d\psi} = \frac{-\left[p - \overline{R}(\mu^*)\right](1-\mu^*)}{\left[\overline{R}'(\mu^*)(1-\psi) + K''(\mu^*)\right](1-\mu^*) - \psi\left[(1+\tau)\overline{R}(\mu^*) - p\right]} < 0, \tag{B.20}$$

where the sign follows from $(1+\tau)\overline{R}(\mu^*) - p < 0$ together with assumed strict quasiconcavity of the bank's program to choose μ^*. In words, a higher level of securitization ψ leads to a lower average loan quality. Recall that the threshold $\widetilde{\delta}$ in Proposition B.4 is strictly decreasing in μ^*. Taken together, these observations mirror the empirical predictions of Section 4.3–i.e., the relation between securitization, loan quality, and steep and short-term bonus pay for the bank's agent.

As a final step in the characterization of the outcome without regulation, the bank sets ψ to maximize its ex-ante payoff, which, after substituting (B.17) into (B.18), yields for its payoffs the derivative

$$\tau \int_{\mu^*}^{1} \overline{R}(\mu) dF + \frac{d\mu^*}{d\psi}\left[-K'(\mu^*) - f(\mu^*)\left[\eta(\mu^*) + \tau\overline{R}(\mu^*)\psi\right]\right].$$

We simplify this again by using that $f(\mu) = 1$, such that we obtain the first-order condition

$$\tau\left[\frac{1}{2}\overline{R}'(1-\mu^*)^2 + (1-\mu^*)\overline{R}(\mu^*)\right] - \frac{d\mu^*}{d\psi}\left[K'(\mu^*) + \eta(\mu^*) + \tau\overline{R}(\mu^*)\psi\right] = 0. \tag{B.21}$$

Assuming strict quasiconcavity of the bank's program at this stage and restricting attention to the case of an interior solution, we have the following characterization.

Proposition B.5 *The bank chooses the level of securitization ψ to satisfy the first-order condition (B.21). The resulting price of the securities, p, together with the prevailing equilibrium quality of loans, as characterized by the cutoff μ^*, are then obtained uniquely from conditions (B.17) and (B.19). Finally, the corresponding optimal compensation contract is given by Proposition B.4.*

Regulation. Recall from Section 5 that mandatory deferred bonus pay can only lead to the "good equilibrium" when it makes it for the bank *relatively* cheaper to incentivize the agent to screen out bad loans. Now, where loan quality is continuous, this requires that $K_2'(\mu^*) < K_1'(\mu^*)$ (at the relevant values of μ^*; see below). Otherwise, mandatory deferred pay can, once again, have the unintended consequence of reducing μ^*. To show this, we proceed in several steps. We first obtain the following auxiliary result, which is analogous to Proposition 4.

Lemma B.1 *For given μ^*, mandatory deferred compensation reduces marginal (agency) costs, as $K_2' < K_1'$, if $\delta > \widehat{\delta}$ holds, where $0 < \widehat{\delta} < \widetilde{\delta}$ is given by*

$$\frac{\widehat{\delta}}{1-\widehat{\delta}} := \frac{1}{2}\left(\frac{2q-1}{1-q}\right)(1-\mu^*)\,\gamma_G. \tag{B.22}$$

Marginal costs increase, as $K_2' > K_1'$, if $\delta < \widehat{\delta}$. If $\delta = \widehat{\delta}$, marginal costs stay the same, as $K_2' = K_1'$.

Proof. We obtain from a comparison of K_2' and K_1' the cutoff

$$\frac{\widehat{\delta}}{1-\widehat{\delta}} := \left(\frac{2q-1}{1-q}\right)\left[\int_{\mu^*}^{1}\gamma(\mu)dF - f(\mu^*)\gamma(\mu^*)\int_{\mu^*}^{1}(\mu-\mu^*)\frac{dF}{1-F(\mu^*)}\right].$$

Then, using $f(\mu) = 1$, we obtain more explicitly

$$K_2' - K_1' = c\left(\frac{1-\delta}{\delta}\right)\frac{2}{(1-\mu^*)^2}\gamma_G - c\frac{4}{(1-\mu^*)^3}\left(\frac{1-q}{2q-1}\right),$$

from which we have $\widehat{\delta}$ as in (B.22). **Q.E.D.**

Consider first the level of securitization ψ as being fixed. Then, we can use Lemma B.1 to see that regulation leads to lower average loan quality (lower μ^*) when $\delta < \widehat{\delta}$, where $\widehat{\delta}$ is evaluated at the cutoff μ^* that arises without regulation. Observe first that with $\delta < \widehat{\delta}$ the optimal compensation without regulation involved early bonus pay. Recall next that, for given ψ, the equilibrium is characterized by the intersection of $\mu^*(p)$ (downward sloping) and $p(\widehat{\mu}^*)$ (upward sloping). Clearly, policy intervention does not affect $p(\widehat{\mu}^*)$. We show that when evaluated at the equilibrium price prevailing before regulation, p, the bank's optimal cutoff μ^* under regulation is, in fact, strictly lower. Together with the characterization from the intersection of $\mu^*(p)$ and $p(\widehat{\mu}^*)$ this yields that the true equilibrium cutoff under regulation is indeed strictly lower (and that the price is lower as well). Consider the equilibrium without regulation, yielding some p and μ^*. After regulation, we have to replace K_1' by $K_2' > K_1'$ in (B.19). From $\delta < \widehat{\delta}$, when evaluated at this pair (p, μ^*) the respective derivative is now, however, strictly negative, which from strict quasiconcavity implies indeed that, given p, the bank's true optimal choice of μ^* must now be strictly lower.

In what follows, we extend this argument to the case where ψ is endogenous and adjusts optimally under regulation. For this it is helpful to reformulate (B.21), using (B.19), to get the simplified first-order condition for ψ,

$$\tau \int_{\mu^*}^{1} \overline{R}(\mu) dF - \frac{d\mu^*}{d\psi} \left[K'(\mu^*) + f(\mu^*)\eta(\mu^*) \right] \frac{p - (1+\tau)\overline{R}(\mu^*)}{p - \overline{R}(\mu^*)} = 0. \tag{B.23}$$

Condition (B.23) implicitly defines the optimal level of securitization, albeit now in terms of the resulting μ^*. (Recall that there is a one-to-one relationship between ψ and μ^*.) Now, if δ is sufficiently low, introducing mandatory deferred pay has two effects that together lead to the unintended consequence of increasing ψ and, thus, reducing μ^*. First, for a given level of securitization, the bank wants to implement a lower μ^* for any price p (this is the effect that we just discussed in isolation by keeping ψ fixed). Second, the "disciplining role" of retention becomes weaker, as $d\mu^*/d\psi$ goes up.

To see this, recall that (B.23) defines $\mu^*(p)$ when ψ is optimally chosen ex-ante. Therefore, we can apply a similar logic as with fixed securitization: The curve $\mu^*(p)$ is again shifted to the left, while investor's willingness-to-pay curve remains unchanged. Thus, the new equilibrium μ^* goes down and the equilibrium ψ goes up. These findings are summarized in the next proposition.

Proposition B.6 *Taking ψ as given, mandatory deferred pay has the unintended consequence of leading to a lower μ^*, if $\delta < \widehat{\delta}$. Furthermore, also if ψ is chosen optimally, mandatory deferred pay can lead to a lower μ^* if δ is sufficiently low.*

Proof. Given our argument in the main text, the result with fixed ψ follows immediately from Lemma B.1 and strict quasiconcavity. If ψ is chosen optimally, given strict quasiconcavity, we have to show that, for sufficiently low δ, the LHS of (B.23) becomes positive if

K_1 is replaced by K_2. Once we substitute $d\mu^*/d\psi$ from (B.20) and rearrange, we see that this would clearly be the case if the term

$$-\frac{R'(\mu^*)(1-\psi)+K''(\mu^*)}{-K'(\mu^*)-f(\mu^*)\eta(\mu^*)}<0$$

decreases. Since we already know that $K_2' > K_1'$ for $\delta < \widehat{\delta}$, it remains to be shown that also $K_2'' > K_1''$ for δ sufficiently low. Using $f(\mu) = 1$, we get that

$$K_2''-K_1''=c\left(\frac{1-\delta}{\delta}\right)\frac{4\gamma_G}{(1-\mu^*)^3}-c\frac{12}{(1-\mu^*)^4}\left(\frac{1-q}{2q-1}\right),$$

implying that such a cut off for δ must exist and, furthermore, it satisfies

$$\frac{\delta}{1-\delta}<\frac{1}{3}\left(\frac{2q-1}{1-q}\right)(1-\mu^*)\,\gamma_G.$$

Q.E.D.