Understanding the Role of Certificates of Deposits in Bank Finance*

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Abstract

In environments where banks have superior information on asset quality and investors update their beliefs based on non-contractible signals over time, I show that Certificates of Deposits (CDs) arise as the optimal contract in bank finance. Essentially, CDs allow for maturity transformation while mitigating solvency risks in case of withdrawals. In other words, they are structured to correlate investors' withdrawal decisions with asset quality, which minimizes the cross-subsidies from high- to low-quality banks; while their yield curve provides insurance to high-quality banks against negative shocks that could cause disintermediation or costly liquidation, thus improving allocative efficiency. Hence, I predict that riskier and less profitable banks rely more on CD funding relative to other types of deposits, which in turn rationalizes the negative correlation between bank size and proportion of CDs in banks liabilities.

Keywords: Banks, Deposits, Maturity transformation, Asymmetric information, Allocative efficiency

JEL classification: D61, D82, D86, G21, G32

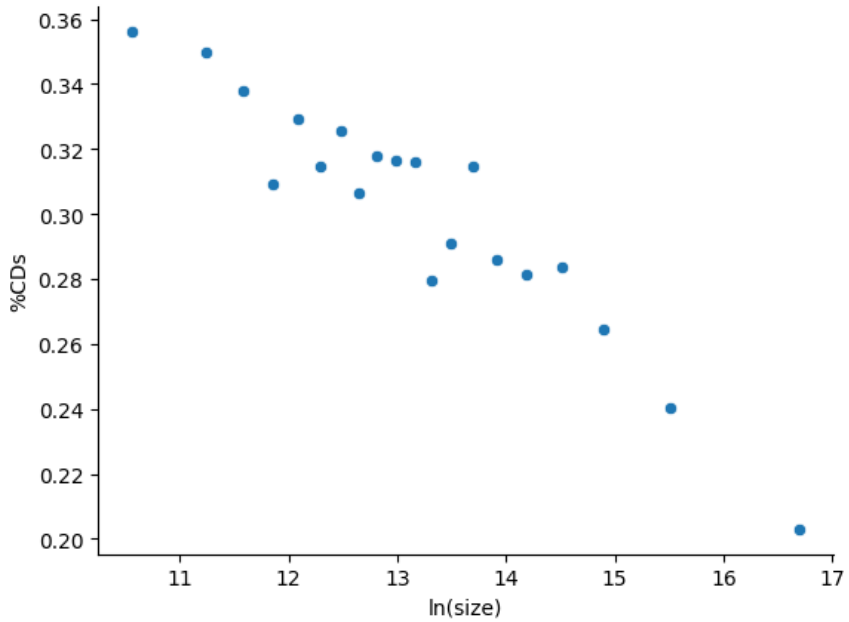
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1. Introduction

Certificates of deposits, an important source of bank funding, have gained recent empirical attention, especially after the 2023 bank crisis given the unsecured nature of large denomination accounts. In this paper, I show that they play a fundamental role in bank finance. That is, In environments where banks have superior information on asset quality and investors update their beliefs based on non-contractible signals over time, I show that CDs arise as the optimal contract. CDs are structured to correlate investors' withdrawal decisions with asset quality, which minimizes the cross-subsidies from high- to low-quality banks; while their yield curve provides insurance to high-quality banks against negative shocks that could cause disintermediation or costly liquidation, thus improving allocative efficiency. The model predicts that riskier and less profitable banks rely more on CD funding relative to other types of deposits, which, in turn, rationalizes the negative correlation between bank size and proportion of CDs in banks liabilities (*figure* 1)[1].

Figure 1: Binscatter Regression



[1]Call Reports data for the fourth quarter of 2024.

Equilibrium analysis reveals patterns that challenge classic intuition. First, I show that the expected duration of the banks' liability structure is u-shaped in the borrower's (bank) credit rating f, contradicting the prediction in Diamond (1991). Second, the cost of capital of high-quality borrowers is hump-shaped in the intensity of the adverse selection problem θ, which can cause a market breakdown for intermediate values of θ, therefore, contradicting classic intuition on static adverse selection and ex-post moral hazard models (e.g, Akerlof (1970), Calomiris and Kahn (1991)).[2] Third, low-quality borrower profits increase in the intensity of the adverse selection problem for low of θ, but are flat and zero for higher values of θ, which goes against the prediction from classic adverse selection models such as Akerlof (1970) and Nachman and Noe (1994).

Contrary to the empirical literature on banking, which usually sets the duration of savings deposits to zero and of certificates of deposits to their specified maturity (e.g, Drechsler et al. (2021), Fleckenstein and Longstaff (2024)), I define an expected duration measure for banks liability structure, which will depend on the equilibrium withdrawals from depositors. When banks' credit rating f is relatively low, the economy's equilibrium will be separating, that is, high-quality borrowers will make risky loans, while low-quality borrowers will prefer to invest in risk-free bonds. In that case, the expected duration will be high, given that depositors anticipate that only high-quality borrowers invested in the risky asset and, therefore, there is no need to withdraw, absent any liquidity shock. On the other hand, when the credit rating improves, separation becomes too costly. Low- and high-quality banks invest in the risky asset after issuing deposits, which will induce investors to withdraw after a credit downgrade, implying a shorter expected duration. This will cause an immediate drop in the expected duration, which then increases in the credit rating f, as the probability of a credit upgrade is higher for higher values of f. The u-shape follows immediately from the fact that, after a credit upgrade, investors do not withdraw their deposits as they become confident in the banks' repayment capacity.

The results on the cost of capital and market breakdown come from investors' participation constraint under the separating and the pooling equilibrium. A separation menu will be feasi-

[2] θ measures the dispersion between high- and low-quality loans cash flows.

ble only if θ is small enough $\theta < \underline{\theta}$, since we need to satisfy the incentive compatibility of the low-quality bank to not invest in the risky asset, which is binding and tightens in θ. On the other hand, given that low-quality banks have negative NPV loans, the pooling equilibrium will be feasible only if θ is large enough $\theta > \bar{\theta}$. Hence, when the return on risky loans x is relatively small, there will be a wedge between $\underline{\theta}$ and $\bar{\theta}$, so that whenever $\underline{\theta} < \theta < \bar{\theta}$, raising capital is not feasible, as it would require a return on capital greater than x. This result adds some non-linearity to market breakdown predictions, contrasting with the usual outcomes from static adverse selection or ex-post moral hazard models, where the market breaks down for low values of θ only.

With regard to low-quality banks' profits, it is expected that they increase in the intensity of the adverse selection problem for low values of θ. As discussed above, in a separating equilibrium, the incentive compatibility of a low-quality bank to not invest in the risky asset tightens in θ. However, for larger values of θ, the market does not break down when the return on risky loans is large enough. Banks would be pooling in equilibrium, but low-quality banks will be forced to pledge the entire cash flows of risky loans after withdrawals as the adverse selection problem is pervasive, which pushes their expected profits to zero.

In line with recent empirical results, banks generally do not size down, but instead react by borrowing more after negative shocks. As predicted, banks facing withdrawals are those with worse fundamentals, and the prediction of a u-shaped expected duration might help explain why banks with worse fundamentals than run banks do not face large withdrawals after negative shocks (e.g., Pérignon et al. (2018), Cipriani et al. (2024)).

In a model extension where a fraction of depositors are unsophisticated and unable to learn the quality of banks' loans, I show that an endogenous staggered intermediation could arise in which the sophisticated investors will act as an intermediary between the unsophisticated depositors and the bank.[3] Interestingly, to avoid any hold-up problems or profit manipulation, the new intermediary will raise money by issuing equity plus deposits, while the original bank will keep optimally issuing demandable debt (deposits). This liability structure guarantees that

[3]Glode and Opp (2016) also show that intermediation chains can improve efficiency in a trade with asymmetric information environment.

the sophisticated investor, acting as an intermediary, will have proper incentives to optimally withdraw their deposits. In particular, the deposits issued will prevent the sophisticated from threatening to not withdraw after a credit downgrade, holding up the unsophisticated, while the equity part guarantees that they do not suboptimally liquidate after an upgrade, in order to profit from renegotiated terms with the initial borrower.

Alternatively, if this staggered intermediation is institutionally too costly, I show that the same allocation is achieved through an FDIC insurance policy. In line with recent empirical studies (e.g., see Egan et al. (2017); Iyer et al. (2016); Chen et al. (2022); Chen et al. (2024); Martin et al. (2024); Cipriani et al. (2024)), sophisticated and uninsured depositors will be sensitive to solvency risks, which will prompt them to withdraw after negative news arrives, while insured depositors can be sticky without posing any negative consequences to banks' date-zero cost of capital. In summary, the FDIC acts as an informed agent, charging an insurance premium from downgraded banks in order to mimic the optimal withdrawal decisions of sophisticated investors on behalf of the unsophisticated. Consequently, the FDIC policy, in the absence of any market solution, helps banks achieve the most efficient outcome by preventing inefficient liquidation, a common feature found in the literature on deposit insurance (e.g., see Diamond and Dybvig (1983); Repullo (2000); Martin (2006); Hanson et al. (2015)).

Finally, I show that, in an environment where investment is scalable with concave marginal returns, safety and loan profitability translates into bank size; and that extremely safe banks will expand their balance sheet by issuing standard savings deposits and selling credit default swaps (CDSs) on their risky loans. Essentially, in addition to making risky loans, banks invest in liquid securities and post them as collateral to capture more deposits, since it is cheap for high-quality banks to sell insurance when they have balance sheet capacity.[4]

[4]This result contrasts credit risk hedging stories such as Parlour and Winton (2013) as banks' short position on CDSs is positively correlated with their loan exposure to a particular firm (e.g., Hasan and Wu (2016), Caglio et al. (2016)).

Related Literature

This paper is mostly related to the literature on the role played by certificates of deposits in bank finance. Dating back to at least Bryant (1980) and Diamond and Dybvig (1983), there is an extensive literature exploring the demand side of certificates of deposits and how they allow depositors to share the risks of unobservable liquidity shocks.[5] That is, risk-averse depositors would pool their capital in exchange for term deposits with pre-determined short- and long-term yields in order to share the risks of future needs of cash. However, these models do not match some empirical patterns observed in the banking literature, such as the correlation between withdrawals and asset quality (e.g., Pérignon et al. (2018), Cipriani et al. (2024)).

The closest supply side story of CDs is the one in Calomiris and Kahn (1991). There, demand deposits discipline banks in an ex-post moral hazard environment, and even though banks with worse fundamentals are more likely to face withdrawals, they show that CDs are issued by safer and more profitable banks, while the riskier and less profitable ones rely on traditional deposits that may force them into liquidation. Supported by Call Reports data and in line with the evidence in Supera (2021)[6], I show that it is exactly the opposite.

More broadly, this paper is related to the literature on the coexistence of deposit-taking and long-term lending in dynamic asymmetric information models. While Flannery (1986), Diamond (1991), and Diamond (1993) have overlooked a potential role for demand deposits, others have abstracted away the information friction from the contracting stage or have taken deposit flows as given.

In Lucas and McDonald (1992), borrowers learn over time the past returns of their portfolio of loans. So, there is no asymmetric information at the funding stage, but only over time. Moreover, they assume that the inflow/outflow of deposits is exogenous and not part of the banks optimal capital structure choice. Therefore, without asymmetric information at the funding stage, the capital structure plays no role in the sense discussed here. Stein (1998) studies a framework in which borrowers have private information regarding their assets in place. New loans are assumed to be riskless; therefore, again there would be no role for the capital struc-

[5] See also Jacklin (1987); Chari and Jagannathan (1988); Jacklin and Bhattacharya (1988); Farhi et al. (2009).

[6] CD funding is positive correlated with Commercial and Industrial ($C\&I$) loans.

ture as discussed in this paper given that one could contingent the provision of new capital to claims of new loans instead of the assets in place.

In Chu (1999), the bank has private information about the quality of its loans. However, similar to Lucas and McDonald (1992), the deposit inflow is determined exogenously, while the asset structure is chosen after this exogenous capital inflow. He claims that higher-quality banks will have incentives to hold a higher percentage of their assets in the form of risk-free securities. In contrast, I show that, when the adverse selection problem is severe, higher-quality banks will offer a menu of contracts that induce separation at the investment stage, causing lower-quality borrowers to hold risk-free securities, and thus abstaining from investing in risky loans. Kashyap et al. (2002) attribute the coexistence of lending and deposit taking to the synergies between these two activities in sharing the deadweight losses of holding liquid assets. However, they also assume an exogenous inflow of deposits at the funding stage, and information asymmetries only arise at a later date, when banks have to raise external funding to fulfill withdrawals motivated by private liquidity shocks.

The remainder of the paper is devoted to formalizing the ideas and results discussed in the Introduction. Section 2 presents the model, outlines the constrained pareto-efficient allocation, and proposes a game to implement the efficient allocation. Sections 3 and 4 present the equilibrium outcomes of agents' interactions, while Section 5 shows some comparative statics. Section 6 extends the baseline model by introducing the presence of unsophisticated investors at $t = 0$ and discussing the policy implications that can be used to alleviate some of the inefficiencies seen throughout the analysis. Section 7 concludes the paper.

2. Baseline Model

I embrace the dynamic adverse selection model with exogenous learning as in Diamond (1991), applied to a banking environment.

Environment. Time is discrete and runs for two periods with three dates: $t = 0, 1, 2$. At $t = 0$, a risk-neutral borrower (bank) has a project to finance that requires raising 1 dollar from external investors. At each date $t \in \{0, 1\}$ there is a unit supply of risk-neutral capital.

The project can be either "Good" (G), producing a cash flow $x > 1$ with certainty ($p_G = 1$) at $t = 2$, or "Bad" (B), in which case it yields the same cash flow x with probability $p_B = \theta$ and 0, otherwise. The bank has private information on the quality of the project and enjoys a non-pecuniary rent $c > 0$ if it remains in control of the loan at $t = 2$.[7] At $t = 0$, investors assign probability f (credit rating) that the bank's project is of type G and $1 - f$ to being of type B. At $t = 1$, investors receive additional non-verifiable, therefore non-contractible, information $r \in \{d, u\}$ regarding the project's type, which can be either a credit rating downgrade $r = d$, or upgrade $r = u$. Denote by f^d and f^u, the conditional probability that the project is of type G given a downgrade or an upgrade, respectively. I assume that $1 = f^u > f > f^d = \frac{f}{m}$, where $m > 1$. Therefore, all type B projects receive a downgrade ($e_B = 1$), and type G projects receive a downgrade with probability $e_G = \frac{f^d(1-f)}{f(1-f^d)} = \frac{1-f}{m-f}$. Agents do not discount cash flows; that is, the short-term gross risk-free rate is equal to one, and everyone is protected by limited liability. A type B project has a negative NPV relative to the safe asset's return, i.e. $\theta x < 1 < x$, whereas a type G project has a positive NPV. Finally, let us denote a borrower with a type-G project as a high-quality or high-type borrower, and low-quality or low-type for a borrower with a type-B project.

2.1. Optimal Allocation

Following Myerson (1983), I solve the problem of a "competitive" planner who seeks to maximize the expected profits of a high-quality borrower (bank), subject to incentive compatibility, feasibility, and participation constraints. The planner can issue either a pooling contract or a separating menu. In general, the planner cannot offer contingent contracts as the model assumes that the signal observed by investors at $t = 1$ is not verifiable and therefore not contractible. However, as I show later, contingent outcomes are possible when we have pooling plus puttability of the debt. Notice that any contingent plan is only achieved through the presence of date-one investors bringing "new" money to supply any demand from date-zero investors when they update their information regarding the project quality at $t = 1$. Additionally,

[7] The positive control rent could also be interpreted as a negative private output in case of disintermediation or costly renegotiation. This could reflect stigma or a lower present value of future income.

as shown by *Lemma* 4, puttability of the debt loses its effect when we have a separating equilibrium. Hence, we are back at solving the non-contingent planner's problem for a separating menu.

Contingent Planner (Pooling). I start by characterizing the pooling planner's allocation. Denote by $q \equiv f^d + (1 - f^d)\theta$, the date-one probability of repayment conditional on $r = d$. Generally, a contract for the contingent planner is a tuple $K_c = (I, l, z_{0,1}, z_{0,2}, z_1)$, of (i) borrowed amount $I = 1$ from date-zero investors; (ii) payment $z_{0,1}$ to date-zero investors at $t = 1$ contingent on $r = d$; (iii) payment $z_{0,2}$ to date-zero investors at time $t = 2$ contingent on $r = u$; and (iv) payment z_1 to date-one investors at time $t = 2$.

Assumption. $qx \leqslant 1$. I focus attention on cases in which, upon negative news, the expected return of a project is smaller than the required investment at $t = 0$.

Definition. A contingent contract is **feasible** if it satisfies limited liability and the contingency constraint. Limited liability implies that $0 \leqslant z_{0,2} \leqslant x$ and $0 \leqslant z_1 \leqslant x$ when the project is successful. The contingency constraint requires that $z_{0,2} \geqslant z_{0,1}$ and $z_{0,1} \geqslant q z_{0,2}$.[8]

For any feasible contract offered by the planner, the payoff of the high-quality borrower is

$$U_G^c(K_c) \equiv e_G(x + c - z_1) + (1 - e_G)(x + c - z_{0,2})$$

The planner's profits are then defined as

$$\pi^c \equiv [f e_G + (1 - f)] z_{0,1} + f(1 - e_G) z_{0,2} - 1$$

where $z_{0,1}$ comes from the zero profit condition of date-one investors. That is,

$$\pi_1^c(d) \equiv \left[f^d + \left(1 - f^d\right)\theta\right] z_1 = z_{0,1}$$

I define the contingent planner's problem (c-PP) as follows:

[8] This guarantees that the planner is not offering state contingent contracts, but allowing for state contingent outcomes to rise naturally from the time one interaction between date-zero investors, the bank, and date-one investors. This is simply the Revelation Principle at work.

$$\max_{K_c} \quad U_G^c(K_c) \tag{c-PP}$$

$$\text{subject to :}$$

$$\pi^c(K_c) \geqslant 0 \tag{PC}$$

$$K_c \text{ is feasible}$$

That is, the planner is maximizing the payoff of a good borrower subject to feasibility and investors' participation constraints, i.e, the planner is not making losses in expectation. *Lemma* 1, in the appendix, characterizes the contingent planner solution when we have pooling.

By raising money at $t = 1$ from date-one investors when $r = d$, the planner can offer contingent payments to date-zero investors to the extent that they satisfy feasibility. Intuitively, a planner that maximizes the utility of a high-quality borrower wants to reduce the adverse selection problem it faces by forcing low-quality borrowers to pay the most as they possibly can, while preventing the high-type from getting liquidated. This is achieved when borrowers raise capital at $t = 1$ after a downgrade to pay initial investors. When $qx > 1$, they cannot go all the way, otherwise they would be violating the contingency constraint, and thus feasibility.

Non-Contingent Planner (Separation). Given that the low-type has a negative NPV project, the planner would like to pay a certain amount to him at $t = 0$ to avoid making more losses in expectation. Thus, a non-contingent separating menu is a pair (y, M) of: (i) cash transfer y to the borrower at $t = 0$; or (ii) a 1 dollar transfer to the borrower at $t = 0$, contingent on him taking the investment opportunity, in exchange for a $t = 2$ payment M to the investor.

Definition. A menu (y, M) is **incentive compatible**, i.e., it separates high- from low-quality borrowers, if it satisfies $y \geqslant \theta(x + c - M)$. Moreover, it is **feasible** if $M \leqslant x$.

For any incentive compatible menu offered by the planner, the payoff of the high-type is

$$U_G^{nc}(y, D) \equiv x + c - M$$

while the planner's expected profits are

$$\pi^{nc}(y, M) \equiv f\,(M-1) - (1-f)y$$

Therefore, I define the non-contingent planner's problem (nc-PP) as follows:

$$\begin{aligned} &\max_{y,M} \quad U_G^{nc}(y, M) && \text{(nc-PP)}\\ &\text{subject to :}\\ &\qquad y \geqslant \theta(x + c - M) && \text{(IC-B)}\\ &\qquad \pi^{nc}(y, M) \geqslant 0 && \text{(PC)}\\ &\qquad M \leqslant x && \text{(Feasibility)} \end{aligned}$$

Lemma 2, in the appendix, characterizes the non-contingent allocation. Notice that the separation cost increases in θ. Hence, when the adverse selection problem is severe, i.e., when θ is small, it will always be optimal to separate. Alternatively, the next proposition shows that if high-quality borrowers get downgraded with a relatively small probability, the pooling allocation will dominate the separating one in cases where the adverse selection problem is mild.

Proposition 1.

Let K_c^* be a solution to either (c-PP) or (c-PP'), and let (y^*, M^*) be a solution to (nc-PP). If $m > \underline{m}$, there will be $\theta_{\underline{m}} < \frac{1}{x}$ such that $U_G^c(K_c^*) > U_G^{nc}(y^*, M^*)$ if $\theta \geqslant \theta_{\underline{m}}$.

Proof.

All proofs are in the appendix. □

The optimality of the separating menu will depend on how strong is the adverse selection problem faced by investors at $t = 0$. That is, if θ is small, the low-quality borrower destroys a lot of resources if the risky investment is taken, thus separation will be optimal in such cases. On the other hand, as the low-type project NPV becomes less negative, the cost of separation increases — we need a higher cash transfer to satisfy the low-quality borrower incentive compatibility constraint of not investing — and therefore, pooling both types becomes efficient given that the cross subsidization decreases with θ.

2.2. Implementation

As usual in the informed principal literature, I will use a two-stage signaling game. It is well known that this type of game generally admits multiple equilibria (e.g., Bernhardt et al. (2022)). Therefore, motivated by the planner's allocation, which I present subsequently, I will restrict attention to contracts in which investors make zero profits in expectation.[9]

Date-zero contracts. At $t = 0$, the bank raises one dollar by issuing a menu of contracts containing a puttable debt [10] (D, F) and a long-term debt with face value ϕ. Formally, the bank demands a quantity of capital $I = 1$, chooses a $t = 1$ withdrawal payment $D \leqslant qx$, a $t = 2$ non-withdrawal payment F, and sets ϕ. Then, if and only if the menu is accepted, the bank chooses either to invest in the risky asset and issue the puttable debt within the proposed menu, or to invest in the riskless security and issue the long-term debt. On the other hand, if the menu is not accepted, the game ends immediately. In summary, a date-zero menu offered by the bank is a tuple $K_0 = (\{D, F\}; \{\phi\})$, upon which investors choose to accept it or not. Hence, denote by $\mathbb{K}_0 = K_0 \cup \{a\}$ the date-zero menu where, upon acceptance ($a = 1$), investors provide the borrower with an amount of capital $I = 1$, and receive the puttable debt (D, F) when the bank invests in the risky asset, or the long-term debt ϕ.

Notice that the face value and withdrawal conditions for the puttable debt cannot be made contingent on the credit rating update realized at $t = 1$. This implies that the withdrawal decision at $t = 1$ has to be ex-post optimal for the investors, which will be achieved by a subgame perfection constraint at the implementation. Hence, the dynamics of the game becomes relevant.

Date-one contracts. At $t = 1$ the bank raises capital by issuing short-term debt when needed. Date-zero investors choose whether to withdraw $W(r) = D$, forcing the bank to raise $W(r)$, or not $W(r) = 0$. Date-one investors then compete for the rate $S(r)$. Thus, a date-one contract is a pair $K_1 = (W, S)$, where W is the amount raised at $t = 1$, and SW is the face value

[9] The canonical paper that imposes zero profits for investors in an informed principal framework is Nachman and Noe (1994). Alternatively, Diasakos and Koufopoulos (2018) propose an endogenous commitment game and show that it implements the ex-ante efficient allocation for informed principal problems.

[10] for example, a mix of savings and certificates of deposits.

at $t = 2$. If $x < SW$, no cash is raised at $t = 1$ and the bank defaults on the withdrawal choices of date-zero investors, losing control over its assets. Otherwise, the bank raises W in short-term debt and proceeds to the next period.

Payoffs. Fix a feasible date-zero contract $\mathbb{K}_0$ and suppose that the investor's withdrawal decision at $t = 1$ does not force the bank to default ($\delta = 0$). Then, a high-quality bank gets the following payoff,

$$U_G(\mathbb{K}_0, K_1, W, i) \equiv \mathbb{1}_{i=risky}\left[x + c - e_G\left(\frac{F}{D}(D - W(d)) + W(d)S(d)\right) - (1 - e_G)\left(\frac{F}{D}(D - W(u)) - W(u)S(u)\right)\right] + \mathbb{1}_{i=riskless}(1 - \phi)$$

and a low-quality borrower gets

$$U_B(\mathbb{K}_0, K_1, W, i) \equiv \mathbb{1}_{i=risky}\theta\left[x + c - \left(\frac{F}{D}(D - W(d)) + W(d)S(d)\right)\right] + \mathbb{1}_{i=riskless}(1 - \phi)$$

Whereas, upon default ($\delta = 1$) at $t = 1$, the bank's expected payoff is zero as it loses control over the assets. The expected profits of the competitive date-zero investors will depend on whether they expect the borrower types to pool and both invest in the risky asset or to separate. Thus, their expected profits at $t = 0$ are

$$\pi_0^{pool} \equiv f(1 - e_G)\left(\frac{F}{D}(D - W(u)) + W(u)\right) + [f e_G + (1 - f)\theta]\left(\frac{F}{D}(D - W(d)) + W(d)\right) + (1 - f)(1 - \theta)W(d) - 1$$

and

$$\pi_0^{sep} \equiv f\left[e_G\left(\frac{F}{D}(D - W(d)) + W(d)\right) + (1 - e_G)\left(\frac{F}{D}(D - W(u)) + W(u)\right) - 1\right] + (1 - f)(\phi - 1)$$

It is implicit that both types of borrowers are pooling in the equilibrium menu they offer. The low-type will always mimic the high-type borrower, otherwise investors would never ac-

cept the menu offered by the former given that the low-quality project is negative NPV.[11] At $t = 1$, given that the investment opportunity was taken at $t = 0$, date-zero investors update their beliefs about the project's cash flow depending on the credit rating update. Thus, letting $q \equiv f^d + (1 - f^d)\theta$, their $t = 1$ expected profits are defined as

$$\pi_{0,1}^{pool}(d) \equiv W(d) + q\frac{F}{D}(D - W(d))$$
$$\pi_{0,1}^{pool}(u) \equiv W(u) + \frac{F}{D}(D - W(u))$$

and

$$\pi_{0,1}^{sep}(d) \equiv \frac{F}{D}(D - W(d)) + W(d)$$
$$\pi_{0,1}^{sep}(u) \equiv \frac{F}{D}(D - W(u)) + W(u)$$

For each date-zero contract in which there is a positive withdrawal, date-one investors then compete to buy the short-term debt the bank issues to pay for the withdrawals. Similar to date-zero investors, their expected profits depend on whether they predict that both borrower types had invested in the risky asset or only the high-type. Thus, if they end up buying the short-term debt after a credit rating downgrade, their expected profits are defined as

$$\pi_1^{pool}(\mathbb{K}_0, W, d) \equiv qS(d)W(d) - W(d)$$

and

$$\pi_1^{sep}(\mathbb{K}_0, W, d) \equiv W(d)S(d) - W(d)$$

[11] It is also implicit in their separating profits definition that, in case of separation at the investment stage, the high-type is investing in the risky asset and the low-type in the riskless security. There cannot be a separating menu in which the low-type invests in the risky asset as it would generate negative profits in expectation for the date-zero investors.

Thus, whenever both types have invested, with probability $q = \left[f^d + (1 - f^d)\theta\right]$ the downgrade comes from a good project or a bad project that becomes successful in $t = 2$, providing date-one investors with the required return $S(d)W$. On the other hand, if they predict that only high-type borrowers are investing in the risky asset, they will get their required return $WS(d)$ for sure. Finally, conditional on a credit upgrade, their profits are defined as

$$\pi_1(\mathbb{K}_0, W, u) \equiv W(u)S(u) - W(u)$$

Equilibrium. Given the nature of the signaling game, investors observe the borrower's menu offer, which makes them potentially update their beliefs about the bank's (project) quality before accepting or rejecting it. Hence, I will analyze the Perfect Bayesian Equilibrium (PBE) satisfying the Intuitive Criterion. Moreover, given the dynamic setting, equilibrium is defined recursively, starting at $t = 1$.

Definition. For a given contract $\mathbb{K}_0$ that implements the $t = 0$ investment, a **date-one equilibrium** consists of a withdrawal decision $W^*(r)$, a date-one contract $K_1^*(\mathbb{K}_0, W^*)$, and a default outcome $\delta^* \in \{0, 1\}$ satisfying:

1. *Withdrawal optimality*: given the posterior belief α_0, W^* is given by:

$$W^*(d) \in \arg\max \pi_{0,1}(d)$$

and

$$W^*(u) \in \arg\max \pi_{0,1}(u)$$

2. *Short-term debt rate*: due to competition, $S^*(r)$ is such that

$$\pi_1(\mathbb{K}_0, W^*, r) = 0$$

3. *Belief consistency*: Denote by α_1 the date-one investors' posterior belief that both types of borrower pooled in equilibrium,

$$\alpha_1 = P(pool|\mathbb{K}_0, W^*, S^*)$$

4. *Default outcome*: given $W^* > 0$,

$$\delta^* = \begin{cases} 1, \text{ if } W^* S^* > x \\ 0, \text{ otherwise.} \end{cases}$$

A date-one equilibrium then consists of an optimal withdrawal decision by date-zero investors, upon which the bank has to raise capital at $t = 1$ to pay for the withdrawals. The short-term debt issued has a competitive rate S^* which implies an expected profit of 0 to date-one investors. If the required rate is such that the bank has to default on the withdrawals, then date-one investors do not provide funds to the bank at $t = 1$. Now we can characterize the date-zero equilibrium.

Definition. A **date-zero equilibrium** consists of a menu K_0^*, a choice of investment $i^* \in \{risky, riskless\}$, and an acceptance decision $a^* \in \{1, 0\}$ satisfying:

1. *Borrower's optimality*: $i_\gamma^* = risky$ if and only if

$$U_\gamma(\mathbb{K}_0^*, K_1^*, W^*, risky) > U_\gamma(\mathbb{K}_0^*, K_1^*, W^*, riskless)$$

2. *Investors' Participation Constraint*: fix a date-zero menu K_0^*. Investors make zero profits in expectation, i.e.,

$$\pi_0(K_0^*) = 0$$

3. *Belief consistency*: Denote by α_0 the date-zero investors' posterior that both types of borrower will pool in equilibrium,

$$\alpha_0 = P(pool|K_0^*)$$

4. *Intuitive Criterion*: The date-zero offer $\hat{K}_0$, inducing $\mathbb{\hat{K}}_0$ and $(\hat{K}_1, \hat{W}, \hat{\delta})$, is not an equilibrium menu if there exists another offer $\tilde{K}_0$, inducing $\mathbb{\tilde{K}}_0$ and $(\tilde{K}_1, \tilde{W}, \tilde{\delta})$, such that

$$U_G(\mathbb{I}\tilde{\mathbb{K}}_0, \tilde{K}_1, \tilde{W}) > U_G(\mathbb{I}\hat{\mathbb{K}}_0, \hat{K}_1, \hat{W})$$

and

$$U_B(\mathbb{I}\tilde{\mathbb{K}}_0, \tilde{K}_1, \tilde{W}) < U_B(\mathbb{I}\hat{\mathbb{K}}_0, \hat{K}_1, \hat{W})$$

5. *Feasibility*: $F^* \leqslant x$

A date-one equilibrium then guarantees that the borrower (bank) is maximizing its utility while anticipating the equilibrium outcome at $t = 1$ induced by the contract offered at $t = 0$.

3. Preliminary Analysis

In this section, I discuss properties of the date-one equilibrium (W^*, K_1^*), given any date-zero contract $\mathbb{K}_0$ that implements the risky investment. *Lemma* 3 shows that, under pooling at the investment stage, deposit withdrawals will occur depending on the withdrawal payment D relative to the long-term payment F, accounting for the credit rating update at $t = 1$.

Intuitively, given a credit rating upgrade, the short-term debt becomes risk-free as investors know for sure that the project will generate a cash flow of x at $t = 2$. Thus, date-zero investors will have no incentives to withdraw after an upgrade. Withdrawal decisions after a downgrade will depend on how costly it is to withdraw relative to the $t = 2$ rate of return. If the withdrawal payment is low enough, they will not withdraw their deposits, while for larger withdrawal payments relative to F, they will withdraw it fully. The short-term rate after a downgrade $S^*(d)$ will be the reciprocal of the project success probability conditional on pooling at the investment stage.

Alternatively, if the date-zero menu implements separation at the investment stage, date-zero investors' behavior will be very different. As I discuss next (*Lemma* 4), the short-term rate is always equal to 1 and date-zero investors do not withdraw their deposits in such a case, which is unexplored in Diamond (1991).

If investors anticipate separation, they know that only the high-quality borrower had invested in the risky asset at $t = 0$, which means that, regardless of the credit rating update, the project will certainly yield a cash flow of x at $t = 2$. Thus, any date-one short-term debt will be riskless and consequently, date-zero investors will have no incentives to withdraw their deposits at $t = 1$ as they are, at the very least, not losing anything by waiting to be paid at $t = 2$. Therefore, any attempt to achieve a contingent allocation will not be feasible if the game induces type separation at the investment stage. Even though date-zero investors are still in control of their withdrawal choices, their optimal behavior in such a scenario will be equivalent to the case where borrowers are issuing only long-term debt, upon which investors would have no withdrawal choice.

As a corollary, we conclude that default is never an equilibrium outcome. We would only observe a default if we have withdrawals and the early cash-out payment is large enough relative to the adverse selection discount, which never happens as $D \leqslant qx$.

4. Equilibrium and the Nature of Certificates of Deposits

After characterizing the optimal withdrawal and short-term debt pricing at $t = 1$ for any date-zero contract, we can now turn our attention to the date-zero equilibrium. By the inscrutability principle (Myerson (1983)) we know that both types of banks will offer the same menu in equilibrium. Essentially, the option to separate types at the investment stage can be attained by the contract selection in the proposed menu. A more direct justification is the fact that since the low-quality bank has a negative NPV project, offering different menus would convey information to investors, who therefore would not accept to put their money down.

In addition, *Lemma* 5 guarantees that in any date-zero equilibrium menu, the high-quality bank profits are maximized. Since investors are making zero profits in expectation, any menu that does not maximize the profits of the high-type will provide the low-quality bank with strictly positive profits in expectation. Therefore, there will exist a profitable deviation for the high-quality bank given that investors are backward looking, i.e., the *intuitive criterion* is satisfied. Hence, the equilibrium contract is derived from the following program:

$$\max_{D,F,\phi} \quad U_G(\mathbb{K}_0, K_1, W) \tag{GP}$$

subject to :

$$\pi_0(K_0) = 0 \tag{PC}$$

$$W(r) \in \arg\max \pi_{0,1}(r) \tag{WC}$$

$$F \leqslant x$$

That is, the equilibrium contract is the one in which a high-quality borrower gets maximum utility subject to investors' participation constraint, withdrawal constraint, and feasibility. *Lemma* 6 characterizes the menu of contracts that implements separation at the investment stage, i.e., the non-contingent planner's allocation.

Under a separation menu, *Lemma* 4 shows that we do not observe withdrawals at $t = 1$. Thus, the withdrawal payment has no relevance to achieve separation at the investment stage. We just need to make sure that the low-quality borrower will not have incentives to invest in the risky asset at $t = 0$, which is achieved when the long-term debt in the date-zero menu carries a relatively large subsidy $(1 - \phi)$. F and ϕ are then jointly determined so that date-zero investors are making zero profits in expectation and the low-type is indifferent between investing in the risky asset or not, guaranteeing that, conditional on separation, we are maximizing the high-type's profits. Separation always comes at a cost, which increases the face value of the debt issued by high-quality borrowers. Notice that, for c small enough, this would be the unique equilibrium if investors did not update their information on the quality of the project at $t = 1$. The game would be a standard signaling game as in Spence (1973), and as shown in Cho and Kreps (1987), the unique PBE that satisfies the intuitive criterion in such signaling games is the most efficient separating equilibrium.

Here, though, investors learn about the project's quality dynamically. Therefore, the possibility of exploiting their belief updating will possibly allow borrowers to achieve contingent outcomes without issuing contingent contracts. This happens only when both types of borrower are pooling in equilibrium, given that investors will potentially have different behavior, at $t = 1$, depending on the credit rating update they observe, as shown in *Lemma* 3. The next

result shows that this is precisely the case. In the pooling equilibrium, the deposit contract issued at $t = 0$ will always induce withdrawals in order to minimize the cross-subsidy between high- and low-quality borrowers.

Proposition 2 (Straight Long-Term Debt Suboptimality)**.**

Suppose that the date-zero equilibrium contract $\mathbb{K}_0^*$ *pools both types of borrowers at the investment stage. Then, it must be true that* $\mathbb{K}_0^*$ *always induce withdrawals at* $t = 1$*. In other words, any date-zero contract which does not induce withdrawals at* $t = 1$ *(e.g., straight long-term debt) cannot be an equilibrium contract.*

The proposition above allows us to better understand the supply side nature of deposits. By delegating the choice of the maturity structure to investors, high-quality borrowers will guarantee that whenever these depositors are actually facing low-quality borrowers, they will be able to extract more of the project's cash flow after a credit downgrade relative to the case where investors are given no choice and the maturity structure is predetermined at $t = 0$. Thus, by allowing investors to get a higher yield after a downgrade, the high-type is able to reduce the yield paid at $t = 2$ after a credit upgrade. That is, by issuing deposits, borrowers can get the benefits of favorable rollover terms after a credit upgrade as if it had issued straight short-term debt, without jeopardizing their solvency after a credit downgrade. This improves efficiency and, consequently, provides high-quality borrowers with extra profits given that they are undervalued at $t = 0$ (*Lemma* 7), whereas low-quality borrowers are overvalued.[12]

By restricting the contract space to straight short- and long-term debt, Flannery (1986) and subsequently Diamond (1991) predict that maturity transformation is at risk due to the costs of liquidation. *Proposition* 2 contradicts this prediction by showing that whenever different types of borrower are pooling in equilibrium, maturity transformation will always occur. In a very similar environment, Diamond (1993) argues that callable debt should improve on the allocation achieved through straight debt.[13] Intuitively, we could set the date-one calling price at qx, thus preventing disintermediation after a credit downgrade. Surprisingly, this would not

[12] I present a numerical example in the appendix.

[13] "Callable debt improves on the straight debt contracts in this model, although puttable debt does not." (Diamond (1993), p. 356).

work because, after a credit upgrade, high-quality borrowers would also have incentives to call the debt back, thus breaking down the callable debt equilibrium at $t = 0$ (*Lemma* 8).

The reason is straightforward. A borrower will always have strictly more incentives to call the debt back after an upgrade relative to a credit downgrade in order to profit from a more favorable rollover pricing. Therefore, we will never be able to improve efficiency in the sense discussed by *Proposition* 2, as we will not be able to provide enough incentives to a low-quality borrower to call it back after a credit downgrade without inducing high-quality borrowers to also call it back after an upgrade. *Lemma* 9 characterizes the date-zero equilibrium under pooling at the investment stage that matches the planner solution from *lemma* 1. Next, I show how a mix of savings and certificates of deposit implements the date-zero equilibrium under pooling.

Proposition 3 (Mix of Savings and Certificates of Deposit)**.**

Let (D^*, F^*) *be the puttable debt parameters from lemma 9. Consider a deposit contract which is composed by a mix of:*

- ρ *certificates of deposits with*
  - *withdrawal payment* ρv*; and*
  - *long-term payment* $\rho\Upsilon = \rho\frac{1-[fe_G+(1-f)]v}{f(1-e_g)}$
- $(1-\rho)$ *savings deposits with*
  - *withdrawal payment* $(1-\rho)$*; and*
  - *long-term payment* $(1-\rho)$

Fix $v \leqslant qx$*. Then, if* $v \geqslant q\Upsilon$*, the mix above implements the date-zero equilibrium under pooling when* $\rho = \frac{1-D^*}{1-v}$*.*

From *lemma* 9 and *proposition* 3 we can notice that the implementation of the contingent planner's allocation can come from the size of the withdrawal penalty or from the proportion

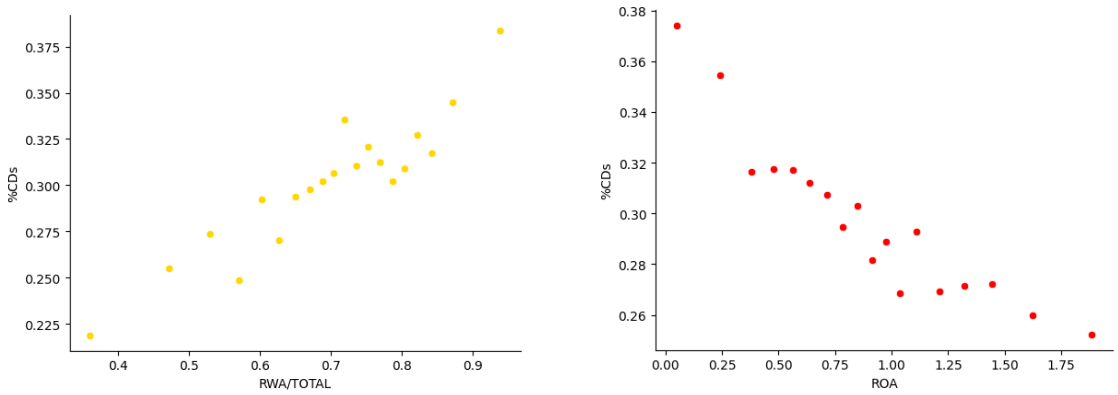
of certificates of deposits relative to savings deposits. Empirically, CDs have a somewhat standardized penalty schedule, while we observe that a considerable amount of the variance in the cross-section of banks comes from the mix of different deposit types on their balance sheets.

Corollary 1.

The proportion of certificates of deposit to total deposits (ρ) *decreases in* f, θ, *and* x.

The previous proposition allows us to make empirical predictions regarding the reliance on certificates of deposit relative to total deposits in the cross section of banks. In contrast to Calomiris and Kahn (1991), the share of CDs to total deposits should be negatively correlated with the safety and profitability of a bank's assets, but in line with the empirical evidence in Supera (2021) which shows a positive correlation between the reliance on CDs and commercial and industrial (C&I) lending. *Figure* 2 presents empirical evidence using Call Reports data for the fourth quarter of 2024.[14]

Figure 2: Binscattered Regressions - 4Q 2024



RWA/TOTAL refers to the proportion of risk-weighted assets to total assets in dollar value, while ROA denotes the return on assets for each bank. Binscatter regressions are performed using banks' asset size and the tier-1 risk-weighted capital ratio as controls.

Finally, given that *lemmas* 4 and 9 is shown to respectively implement the non-contingent and the contingent planner's allocation, the result of *proposition* 1 naturally extends to the proposed game. That is, there will always exist a parameter region in which high-quality borrowers prefer to pool with low-quality ones at the investment stage to profit from the optimal

[14]In the data appendix I provide similar cross-sectional evidence for the time series from 2014 to 2024.

withdrawal decisions of date-zero investors at $t = 1$, after a credit rating downgrade. In particular, this will be true when the probability that the high-type faces a credit downgrade and the adverse selection cost of raising capital are small enough, i.e., $m > \underline{m}$ and $\theta > \hat{\theta}_m$. In other words, the impossibility of issuing state contingent contracts makes the cost of separation increasing as the adverse selection problem decreases. This happens because, in anticipation of separation, investors will always provide the bank with cheap capital at $t = 1$.

The results above show that the solutions proposed by the literature, i.e. a mix of debt maturities or callable debt, does not work for this environment. None of these mechanisms achieve the same allocation as the menu of contracts analyzed here, which implements the ex-ante optimal allocation in Section 2.1. Next, I present some economic intuition behind the optimal contracts derived in the baseline model.

5. Comparative Statics

It is straightforward to calculate the duration of the liability structure when dealing with straight debt. Here, however, we need an alternative definition, given that it would only be ex-post determined after the demand deposits withdrawal decisions have been made. Hence, I define an expected duration measure, one that takes into account, at $t = 0$, the equilibrium outcomes at $t = 1$ given the menu of contracts offered at $t = 0$. That is, given a date-zero equilibrium menu that implements pooling at the investment stage, we have

$$\mathbb{E}\left[MacD_{pool}\right] \equiv \left[f e_G + (1-f)\right] D^*_{pool} + 2f(1-e_G)F^*_{pool} < 2$$

while for a date-zero equilibrium menu that implements separation at the investment stage, we have

$$\mathbb{E}\left[MacD_{sep}\right] \equiv 2\left[f F^*_{sep} + (1-f)\phi^*\right] = 2$$

Notice that, when the date-zero equilibrium menu implements separation at the investment stage, investors will not withdraw their deposits even after a credit downgrade, which will al-

low the high-type borrower to match the duration between its assets and liabilities in expectation. The next result highlights how the expected duration varies with model parameters.[15]

Proposition 4.

The expected duration defined above is generally

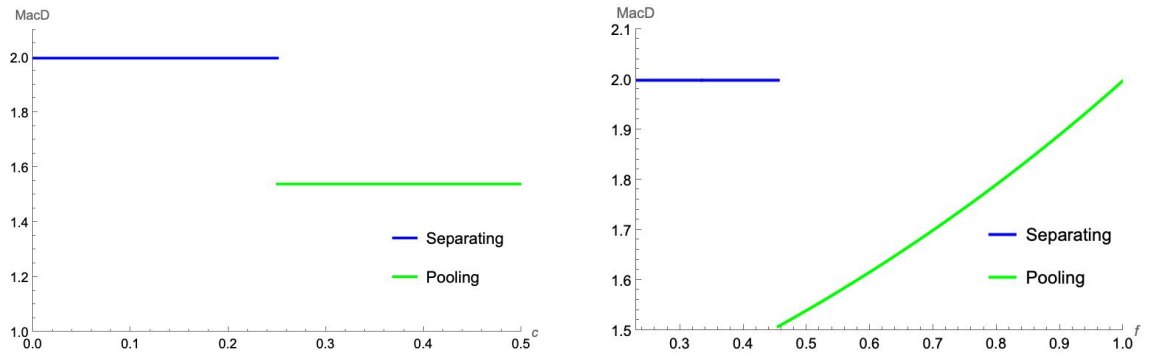
(a) weakly decreasing in the control rent c;

(b) U-shaped in the credit rating f.

Diamond (1991) argues that when the cost of disintermediation is high, i.e., c is large, borrowers would issue straight long-term debt in order to prevent early liquidation, whereas when the liquidation cost is not a concern, i.e., c is small, borrowers would choose a short-term liability structure. In contrast to his results, I show that the duration of the liability structure is non-increasing in c. This happens because, for large values of c, the date-zero equilibrium menu will implement pooling at the investment stage, and, as shown by *Proposition* 9, the equilibrium contractual terms for the deposit contract are independent of c. Moreover, when c is small enough, there will be a parameter region where high-quality borrowers prefer to separate at the investment stage given that the cost of separation decreases in c. As argued above, the separating menu has an expected duration of 2, therefore, the overall expected duration is, in general, weakly decreasing in c (Figure 3, panel (a)).

Also in contrast to Diamond (1991), I show that a high duration liability structure is a feature of low- or high-rated borrowers, while intermediate-rated borrowers front load payments because they are the ones most likely to face withdrawals after being downgraded. The U-shaped duration corroborates the prediction in Koufopoulos et al. (2023). The key difference is that, in their model, the rollover benefits increase in the credit rating for low values of f, leading high-type borrowers to underinvest and to have a liability structure duration that decreases in f for low-rated borrowers. On the other hand, as the adverse selection problem fades (f increases), the benefits of investment dominate the rollover benefits of having a shorter-term liability structure, which leads high-type borrowers to issue straight long-term debt. In

[15] I denote the parameter f as the credit rating of a high quality borrower, and I will refer to θ as the adverse selection problem intensity.



(a) $m = 5$; $x = 1.5$; $\theta = 0.5$; $f = 0.5$ (b) $m = 5$; $x = 1.5$; $\theta = 0.5$; $c = 0.3$

Figure 3: Expected Duration

my model, the main concern is with overinvestment. Therefore, for low-rated borrowers, the adverse selection problem prevents any pooling equilibrium, which then forces low-quality borrowers to not invest in the risky asset, guaranteeing a flat and high expected duration. As the adverse selection problem improves (f increases), pooling becomes the norm, given that investors are able to extract more from borrowers after a credit downgrade. Consequently, the duration increases in f for high-rated borrowers, as the increasing probability of a credit upgrade at $t = 1$ and project success overpower the front-loading terms of the demand deposit contracts ((Figure 3, panel (b)).

The benefit of taking into account the equilibrium outcomes in order to define the expected duration of the liability structure is that it allows us to have a clearer picture with regards to the maturity transformation and, consequently, to the maturity mismatch embedded in banks balance sheets, which can be relevant for assessing systemic risk, for example. If, instead, we were to use the common ex-ante definition of duration for deposit contracts, as in Drechsler et al. (2021) or Fleckenstein and Longstaff (2024), we would have a strikingly different conclusion in terms of maturity mismatch. In particular, the maturity mismatch would be the largest when the intensity of the adverse selection problem is the lowest or the credit rating is the highest (*lemma* 10), an immediate consequence of *corollary* 1.

Proposition 5.

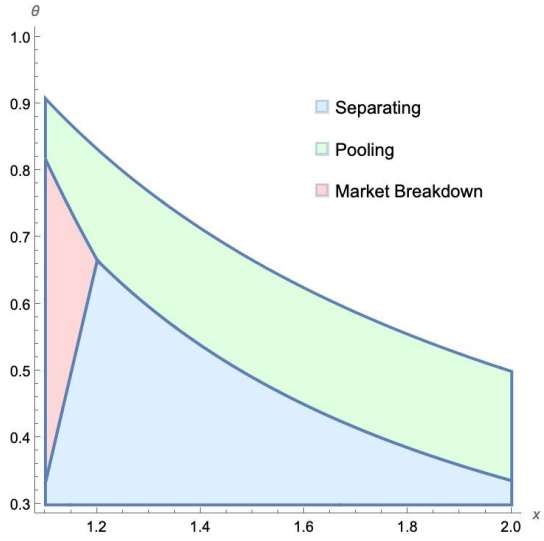
The cost of capital is hump-shaped in the intensity of adverse selection problem θ. As a conse-

quence, there exist $\tilde{x} > 1$, $\underline{\theta}$, *and* $\bar{\theta}$ *with* $\underline{\theta} < \bar{\theta}$, *such that, if* $x < \tilde{x}$, *the market breaks down and we have underinvestment when* $\underline{\theta} < \theta < \bar{\theta}$. *Moreover, there exists* $\underline{f} < \bar{f}$ *such that the cost of capital increases in m if* $\underline{f} < f < \bar{f}$, *for a certain parameter region.*

The first couple of results contradicts classic intuition on static adverse selection and ex-post moral hazard models (e.g., Akerlof (1970); Calomiris and Kahn (1991)). In these models, it is expected that profits increase as we shrink the gap between low- and high-quality goods, or low- and high- cash flows.[16] As a consequence, it is expected that market would only break down for low values of θ. The same intuition applies here when we have pooling at the investment stage as the equilibrium outcome. That is, more cash will be pledgeable, conditional on a credit downgrade, the higher the θ, therefore, reducing the overall cost of capital. However, when θ is small enough, we will have separation at the investment stage, and we know that the cost of separation increases in θ, therefore reducing profits. Hence, market will break down for intermediate values of θ when future revenue x is not high enough to cover for the increasing cost of capital (Figure 4).

Figure 4: Date-zero Equilibrium

$f = 0.5$; $m = 5$; $c = 0.3$



The last part provides a rationale for opaqueness. In general, it is expected that the signal

[16] Keeping the high cash flow fixed.

precision (rating update) about types improves efficiency by reducing the cost of capital.[17] Intuitively, a more precise signal (higher m) reduces the chances that a high-type borrower will get downgraded at $t = 1$. Therefore, given a particular credit rating f, the date-zero probability of repayment at $t = 2$ increases in m, which reduces the cost of capital. The problem is that, by increasing the signal precision, we are worsening the adverse selection problem at $t = 1$ conditional on a credit downgrade.[18] As a consequence, lenders will get a lower $t = 1$ withdrawal payment, which increases the cost of capital. This negative effect on the date-one adverse selection problem is more pronounced for higher-rated borrowers (large f), but the probability of a credit downgrade is higher for lower-rated borrowers. Thus, this positive effect of a higher signal precision on the cost of capital will be relevant for intermediate-rated borrowers, whose profits can therefore increase with opaqueness (lower m). Next, I discuss some low-quality borrowers' profits patterns.

Proposition 6. *There exists $\underline{\theta} > 0$ such that the profits of a low-quality borrower increase in θ for $\theta < \underline{\theta}$, but it is zero for $\theta > \underline{\theta}$.*

This result contradicts the intuition of classic adverse selection models such as Akerlof (1970) and Nachman and Noe (1994), where the profits of a low-type seller or borrower are generally increasing in θ. Here, it is piecewise non-decreasing. For low values of θ, the date-zero equilibrium menu separates borrowers at the investment stage, and we know that the face value of the debt issued by low-quality borrowers ϕ decreases with θ. However, for intermediate values of θ, the optimal menu is pooling and certificates of deposits are issued, forcing low-quality borrowers into zero profits.

To approximate the model to other real-life features of banking, the analysis is extended to explore the case in which a fraction of the bank's supply of capital is unsophisticated and, therefore, uninformed regarding any credit rating update. I show that this has important consequences for banks' capital structure and also that it has relevant policy implications, especially for deposit insurance.[19]

[17] The signal precision in the model is captured by m. If $m \to \infty$, the rating update is fully informative, while when $m = 1$, the update is uninformative.

[18] Notice that $\frac{\partial q}{\partial m} = -\frac{f(1-\theta)}{m^2}$.

[19] In the appendix, I explore two other extensions. One that allows for project scalability, which connects to

6. Model Extensions

In this section, I present the extension mentioned above and examine potential ex-ante inefficiencies that arise relative to the baseline model. Then, I discuss what government policies can help mitigate these inefficiencies.

6.1. Unsophisticated (Sticky) Depositors

Consider an alternative version of the baseline model in which, out of the date-zero dollar supply of capital the borrower has access to, a fraction $(1-\gamma)$ of it comes from investors who observe the credit rating update at $t = 1$, while there is plenty of date-zero supply of capital from investors who do not observe it. Again, for simplicity, I assume that we are always in the pooling region at the investment stage. The next result shows that, when the proportion of capital needed from sticky depositors γ is relatively small, a good borrower can achieve the same level of profits as in the baseline model.

Proposition 7. *There exists $\gamma^* \in (0, qx)$ such that, if $\gamma \leqslant \gamma^*$, the borrower will optimally issue a quantity γ of traditional savings deposits with a gross interest rate equal to one, and a quantity $(1-\gamma)$ of deposits with a withdrawal payment $D = qx - \gamma$ and a long-term non-withdrawal payment $F = \frac{(1-\gamma)-[fe_G+(1-f)](qx-\gamma)}{f(1-e_G)}$.*

The proposition above highlights the fact that when a small fraction of the capital supply is unsophisticated (sticky), banks can still achieve the same level of ex-ante efficiency as in the baseline model. This happens because they are able to adjust the short- and long-term yields of the (time) deposits issued to sophisticated investors in such a way that the incentive compatibility constraint to withdraw after a credit downgrade is still satisfied. In other words, sophisticated investors absorb the potential inefficiencies caused by the lack of information regarding the borrowers' financial health. On the other hand, in the absence of any market

the empirical evidence on the reliance of CDs versus bank size, while the other analyzes the case in which banks' loans are extremely safe, i.e., $qx > 1$. In the latter, it is shown that high-quality banks are funded with traditional savings deposits and sell credit default swaps to minimize the cross-subsidy they pay to low-quality banks.

solution, when the presence of unsophisticated investors is more pervasive in the borrowers' capital structure, then the ability to have a state-contingent liability structure is hampered, which would cause an efficiency loss as "Good" borrowers' profit level is diminished. Alternatively, in such a situation, an endogenous staggered intermediation structure could arise. The next result shows that when sophisticated investors act as an intermediary between the bank and the sitcky depositors, the efficiency from the baseline model is restored.

Proposition 8. *Suppose that $\gamma > \gamma^*$. Consider the following intermediation structure. The bank issues the deposit contract from lemma 9 to a sophisticated investor, who then issues equity plus the same deposit contract to sticky depositors. This guarantees the same profit level as in the baseline model.*

Recall that sticky depositors do not observe the credit update at $t = 1$. Therefore, we need to guarantee that the sophisticated investor, acting as an intermediary, will have proper incentives to optimally withdraw the deposit when needed. Issuing demand deposits will prevent the intermediary from holding up the sticky depositors when $r = d$ against their lack of information. Notice that if straight debt was issued, the intermediary could threaten not to liquidate when $r = d$, and then renegotiate lower payments at $t = 2$. With demand deposits, any threat will be matched by withdrawals, which in turn would force the intermediary to withdraw their deposit from the bank. On the other hand, issuing equity will prevent the intermediary from suboptimally withdrawing at $t = 1$ when $r = u$. If the intermediary retained equity in the venture, she could withdraw when an upgrade is observed and negotiate some profit sharing with the bank, given that, after a credit upgrade, the bank can issue new debt very cheaply.

6.2. Policy Implication - FDIC Insurance

Consider the extension above. *Proposition* 7 showed that, when γ is large enough, there will be potential efficiency losses incurred by the high-quality borrower if the staggered intermediation solution is institutionally too costly. This happens because the fraction of sophisticated investors is small enough to absorb the lack of information from the unsophisticated ones. The next proposition highlights that, when the government commits to charge an insurance pre-

mium from borrowers who get downgraded, then efficiency is restored.

Proposition 9. *Consider the following policy. At $t = 1$, conditional on observing a credit downgrade, the government commits to charge an insurance premium totaling ρ dollars to the bank. At $t = 2$ if the bank fails, the government pays an insurance ρ to date-zero depositors who still hold deposits at the bank, and if the bank is still solvent it gets the premium back. Given this policy, banks can issue the same deposit contract from lemma 9 so that efficiency is restored if*

$$\rho = \gamma F^* + \frac{\rho}{q} - \gamma x \qquad \text{(Optimality Condition)}$$

where $F^* = \frac{1-[fe_G+(1-f)]qx}{f(1-e_G)}$.

The insurance policy guarantees that uninformed investors will get the same expected return that sophisticated investors get conditional on their optimal withdrawal decisions. Lack of information and the presence of insurance creates stickiness that is not harmful to banks profits, as the premium is charged conditional on the credit rating, therefore, providing the same optimality conditions of the baseline model.

7. Conclusion

In a simple principal-agent dynamic asymmetric information model as in Diamond (1991), I show that certificates of deposits are crucial to (i) minimize the cross-subsidy from high- to low-quality banks; and (ii) share risks between banks and depositors and, consequently, avoid inefficient liquidation. The model predicts, with empirical support, that smaller, riskier, and less profitable banks rely more heavily on CDs relative to other types of deposits. Additionally, I show that, while sticky depositors pose a threat to efficiency, as high-quality banks would struggle to minimize the cross-subsidies paid to low-quality ones, an FDIC insurance policy is able to restore efficiency by charging a premium after negative shocks, emulating the optimal withdrawal decisions of sophisticated investors.

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A. Data Appendix

I use Call Reports data from 2014 to 2024. Regressions are performed using data on time deposits ($rconj473+rconj474+rcon6648$), total deposits ($rcon2200$), risk-weighted assets ($rcoaa223$), total assets ($rcon2170$), tier1 risk-weighted capital ratio ($rcoa7206$), and net income ($riad4340$). The following table provides cross-sectional evidence for the time series 2014-2024 similar to the one provided by *figure* 2.

Table 1

Variables	Percentage of CDs to Total Deposits			
%RWA	0.12***	0.10***	0.38***	0.35***
	(8.10)	(6.71)	(20.57)	(17.92)
ROA	-0.10**	-0.10**	-0.20***	-0.19***
	(-2.19)	(-2.02)	(-6.21)	(-5.86)
Controls	No	No	Yes	Yes
Time FE	No	Yes	No	Yes
N	177295	177295	177295	177295

*** p<0.01, ** p<0.05, * p<0.1. Standard errors clustered at the individual level.

The control variables are bank size and the tier1 risk-weighted capital ratio. As shown in the extensions appendix, larger banks can have more profitable assets, therefore, when controlling for size, an increase in ROA should capture an increase in asset profitability. Analogously, when controlling for the tier1 risk-weighted capital ratio, an increase in the proportion of risk-weighted assets relative to total assets can be interpreted as in increase in portfolio risk.[20]

[20] I exclude banks with a tier1 risk-weighted capital ratio greater than 1, which account for less than 3% of the data points.

B. Supporting Lemmas

Lemma 1. *[Contingent Planner Solution]*

The optimal payments, $z^*_{0,1}$ and $z^*_{0,2}$ are the following:

- $z^*_{0,1} = qx$;
- $z^*_{0,2} = \frac{1-[fe_G+(1-f)]z^*_{0,1}}{f(1-e_G)}$

as long as $\theta \geqslant \frac{1-\left[f^d(fe_G+(1-f))+f(1-e_G)\right]x}{[fe_G+(1-f)](1-f^d)x}$.

Proof. Suppose (K^*_c) is a solution to (c-PP).

1st observation. Zero profits — (PC) must bind.

Notice that $z^*_{0,t} > 0$ for some $i \in \{1,2\}$. Fix $z^*_{0,\tau} > 0$. Assume $\pi^c(K^*_c) > 0$. Then, because of continuity, one can set $\hat{z}_{0,\tau} = z^*_{0,\tau} - \varepsilon$, for some $\varepsilon > 0$, such that $\hat{K}_c$ — which is equal to K^*_c except for $z_{0,\tau} = \hat{z}_{0,\tau}$ — is feasible, $\pi_c(\hat{K}_c) > 0$, and $U_G(\hat{K}_c) > U_G(K^*_c)$. Therefore, (K^*_c) cannot be a solution to (c-PP), which implies that (PC) must bind.

2nd Observation. $z^*_{0,1} = qx$, where $q = \left[f^d + (1-f^d)\theta\right]$. That is, we want to pay as most as we can to date-zero investors at $t = 1$, i.e., we want to raise whatever the project allows from date-one investors, conditional on the adverse selection discount after a credit rating downgrade.

Notice that, conditional on no liquidation after a credit downgrade,

$$\frac{\partial U^c_G}{\partial z_{0,1}} = -e_G \frac{\partial z_1}{\partial z_{0,1}} - (1-e_G)\frac{\partial z_{0,2}}{\partial z_{0,1}}$$

From the date-one investors zero profit condition we know that

$$\frac{\partial z_1}{\partial z_{0,1}} = \frac{1}{q}$$

and, from the zero profits condition of date-zero investors we get

$$\frac{\partial z_{0,2}}{\partial z_{0,1}} = -\frac{[f e_G + (1-f)]}{f(1-e_G)}$$

Therefore,

$$\frac{\partial U_G^c}{\partial z_{0,1}} = -\frac{e_G}{q} + \frac{[f e_G + (1-f)]}{f}$$

Notice that, $\frac{dU_G^c}{dz_{0,1}} \geqslant 0$ if

$$\theta \geqslant \frac{f e_G}{(1-f^d)[f e_G + (1-f)]} - \frac{f^d}{1-f^d} \equiv \tilde{\theta}$$

Claim. $\tilde{\theta} = 0$

Rearranging $\tilde{\theta}$ we get

$$\tilde{\theta} = \frac{f e_G - f^d[f e_G + (1-f)]}{(1-f^d)[f e_G + (1-f)]} = \frac{f e_G(1-f^d) - f^d(1-f)}{(1-f^d)[f e_G + (1-f)]}$$

Given that $e_G = \frac{1-f}{m-f}$ we get

$$\tilde{\theta} = \frac{f(1-f)(1-f^d) - f^d(1-f)(m-f)}{(1-f^d)[f e_G + (1-f)](m-f)} = \frac{(1-f)\left[f - f f^d - f^d m + f f^d\right]}{(1-f^d)[f e_G + (1-f)](m-f)} = \frac{(1-f)(f - f^d m)}{(1-f^d)[f e_G + (1-f)](m-f)} = 0$$

given that $f^d = \frac{f}{m}$. Therefore, $\frac{dU_G^c}{dz_{0,1}} \geqslant 0$ for any $\theta \geqslant 0$.

Hence, we want to set $z_1^* = x$, so that $z_{0,1}^* = qx$. We just need to check for feasibility, in particular for the contingency constraint. From date-zero investors' (PC) we get

$$z_{0,2} = \frac{1 - [f e_G + (1-f)] z_{0,1}}{f(1-e_G)}$$

Finally, we need to make sure $z_{0,2} \leqslant x$ to satisfy feasibility. We remain to check if

$$\frac{1 - [f e_G + (1-f)] qx}{f(1-e_G)} \leqslant x$$

That is, $z^*_{0,2}$ will be feasible if and only if

$$\theta \geqslant \frac{1-\left[f^d\left(f e_G+(1-f)\right)+f(1-e_G)\right]x}{[f e_G+(1-f)](1-f^d)x}$$

□

Lemma 2 (Non-Contingent Planner Solution)**.**

The solution to the non-contingent separating planner (y^*, M^*) *is characterized by*

- $M^* = \frac{f+(1-f)\theta(x+c)}{f+(1-f)\theta}$;
- $y^* = \theta(x+c-M^*)$;

as long as $\theta \leqslant \frac{f(x-1)}{(1-f)c}$

Proof.

By similar arguments as in *lemma* 1, both the participation constraint and the incentive compatibility must bind at the optimal solution for the planner's problem. Therefore, from the (IC-B) we have

$$y^* = \theta(x+c-M)$$

and from the (PC) we have

$$f\,(M-1) = (1-f)\theta(x+c-M)$$

which implies that

$$M^* = \frac{f+(1-f)\theta(x+c)}{f+(1-f)\theta}$$

We just need to guarantee feasibility, i.e., $M^* \leqslant x$, that is

$$\theta \leqslant \frac{f(x-1)}{(1-f)c}.$$

□

Lemma 3 (Date-One Equilibrium under Pooling)**.**

Given a date-zero contract $\mathbb{K}_0$ *that implements the* $t = 0$ *investment and* $\alpha_1 = 1$*, we have*

1. $S^*(u) = 1$ *and* $W^*(u) = 0$*;*
2. $W^*(d) = 0$ *if:*
   - $\frac{F}{D} > \frac{1}{q}$*;*
3. $W^*(d) = D$*, otherwise. Hence,* $S^*(d) = \frac{1}{q}$*.*

Proof.

The short-term debt rate S^* is determined competitively by setting date-one investors profits to zero. Thus, under pooling we have

$$\pi_1^{pool}(\mathbb{K}_0, W, u) = W(u)S^*(u) - W(u) = 0$$

which implies that $S^*(u) = 1$. Thus, to determine the optimal withdrawal choice we need to check for the date-zero investors' profits at $t = 1$, that is

$$\pi_{0,1}^{pool}(u) = W(u) + \frac{F}{D}(DI - W(u))$$

Differentiating with respect to $W(u)$ we get

$$\frac{\partial \pi_{0,1}^{pool}(u)}{\partial W(u)} = 1 - \frac{F}{D} \leqslant 0$$

Therefore, $W^*(u) = 0$.

Moving on to the credit downgrade, date-zero investors profits at $t = 1$ are equal to

$$\pi_{0,1}^{pool}(d) = W(d) + q\frac{F}{D}(D - W(d))$$

Differentiating $\pi_{0,1}^{pool}(d)$ with respect to $W(d)$ we get

$$\frac{\partial \pi_{0,1}^{pool}(d, W(d) = 0)}{\partial W(d)} = 1 - q\frac{F}{D}$$

That is, if

$$1 - q\frac{F}{D} < 0$$

We will have $W^*(d) = 0$. Otherwise, $W^*(d) = D$. Additionally, from date-one investors zero-profit condition we have $S^*(d) = \frac{1}{q}$.

□

Lemma 4 (*Date-One Equilibrium under Separation*)**.**

Given a date-zero contract $\mathbb{K}_0$ *that implements the* $t = 0$ *investment and* $\alpha_1 = 0$, $S^*(d) = S^*(u) = 1$ *and date-zero investors do not withdraw at* $t = 1$, *i.e.*, $W^*(u) = W^*(d) = 0$.

Proof.

The short-term debt rate S^* is determined competitively by setting date-one investors profits to zero. Thus, under separation we have

$$\pi_1^{sep}(\mathbb{K}_0, W, d) = W(d)S^*(d) - W(d) = 0$$

and

$$\pi_1^{sep}(\mathbb{K}_0, W, u) = W(u)S^*(u) - W(u) = 0$$

which implies that $S^*(d) = S^*(u) = 1$.

Remember that date-zero investors profits at $t = 1$ are

$$\pi_{0,1}^{sep}(r) = \frac{F}{D}(DI - W(s)) + W(s)$$

Differentiating it with respect to $W(r)$ we get

$$\frac{\partial \pi_{0,1}^{sep}}{\partial W(r)} = 1 - \frac{F}{D} \leqslant 0$$

since $D \leqslant F$, otherwise the CD would be a straight short-term debt. Thus, we conclude that $W^*(u) = W^*(d) = 0$.

□

Corollary 2 (Default Outcome)**.**

Given a date-zero contract $\mathbb{K}_0$*, the optimal withdrawal policy* W^**, and the short-term debt rate of return* S^**,* $\delta^*(r) = 0$*.*

Proof.

Follows immediately from *Lemmas* 4 and 3.

□

Lemma 5. *Any date-zero equilibrium menu* K_0*, inducing* $\mathbb{K}_0$*, maximizes the utility of a high-quality borrower.*

Proof.

I will show that any date-zero equilibrium contract maximizes the utility of a type-G borrower. Suppose by contradiction that it does not. That is, let $\mathbb{K}_0^*$ be a date-zero equilibrium contract which does not maximize the utility of a type-G borrower.

Let $\mathbb{K}'_0$ be a date-zero contract that solves the type-G borrower problem (GP),

$$\max_{I,D,L} \quad U_G(\mathbb{K}_0, K_1, W) \tag{GP}$$

subject to :

$$\pi_0(K_0) = 0 \tag{PC}$$

$$F \leqslant x$$

It must be that $U_G(\mathbb{K}_0', K_1', W') > U_G(\mathbb{K}_0^*, K_1^*, W^*)$, where K_1' and W_1' are the date-one equilibrium contract and the optimal $t = 1$ withdrawal policy induced by $\mathbb{K}_0'$.

Notice that in any date-zero equilibrium contract, the type$-G$ borrower always invest in the risky asset, and it must be true that $U_B(\mathbb{K}_0', K_1', W') < U_B(\mathbb{K}_0^*, K_1^*, W^*)$, otherwise date-zero investors would be making losses in equilibrium, given that both $\mathbb{K}_0^*$ and $\mathbb{K}_0'$ satisfy investors participation constraint. Thus, $\mathbb{K}_0^*$ does not survive the Intuitive Criterion and cannot be a date-zero equilibrium contract.

□

Lemma 6 (Date-zero equilibrium under separation)**.**

A date-zero equilibrium contract $\mathbb{K}_0^*$ *that implements separation at the investment stage is characterized by*

- $D^* \leqslant 1$;
- $\phi^* = 1 - \theta(x + c - F^*)$;
- $F^* = \frac{f+(1-f)\theta(x+c)}{f+(1-f)\theta}$;

as long as $\theta \leqslant \frac{f(x-1)}{(1-f)c}$.

Proof.

Follows immediately from *Lemma* 4 and noticing that this is exactly the non-contingent planner's problem solved in *Lemma 2* if we set $\phi = 1 - y$ and $F = M$.

□

Lemma 7. *If $qx < 1$, straight debt does not implement the planner's solution.*

Proof. Recall that, in the optimal allocation from *Lemma* 1, the high-quality bank gets

$$U_G^{optimal} = e_G c + (1 - e_G)(x + c - z_{0,2}^*)$$

Notice, however, that $z_{0,2}^* = F_{st}$. Therefore, $U_G^{optimal} > U_G^{st}$. □

Lemma 8.

Callable debt is always dominated by straight short or long term debt.

Proof.

Suppose the borrower can call the debt back at $t = 1$ for C, and let the long term payout be denoted by L. Notice that if the borrower calls it back after a downgrade, it would also call it back after an upgrade. The converse is not true. Therefore, if the borrower is calling it back after a credit downgrade then there would be no practical difference between this and a short term debt.

Therefore, we remain to check whether, in the case where the borrower is calling it back only after an upgrade, a callable bond can dominate a long term debt. Notice that, in order for the borrower to call it back only after an upgrade, it must be true that $C < L$ and $\frac{C}{q} > L$.

Date-zero investors' zero profit condition is determined by

$$f\left[e_G L + (1 - e_G)C\right] + (1 - f)\theta L = 1$$

Therefore,

$$L = \frac{1 - f(1 - e_G)C}{f e_G + (1 - f)\theta}$$

To satisfy the incentive compatibility condition above, $\frac{C}{q} > L$, then it must be true that

$$\frac{C}{q} > \frac{1 - f(1 - e_G)C}{f e_G + (1 - f)\theta}$$

which implies that

$$C > \frac{q}{f e_G + (1-f)\theta + f(1-e_G)q}$$

Manipulating the expression above and recalling that $q = f^d + (1-f^d)\theta$, $e_G = \frac{1-f}{m-f}$, and that $f^d = \frac{f}{m}$, we can verify that

$$\frac{q}{f e_G + (1-f)\theta + f(1-e_G)q} = 1$$

Therefore, we will satisfy the incentive compatibility constraint whenever $C > 1$.

We then need to check whether or not there exists a pair (C, L) satisfying this incentive compatibility and such that the type-G borrower's utility is greater than when he issues straight long-term debt.

The utility of a "Good" borrower issuing a callable debt satisfying the incentive compatibility is then defined by

$$U_G^{callable} \equiv x + c - e_G L - (1-e_G)C = x + c - e_G \frac{1 - f(1-e_G)C}{f e_G + (1-f)\theta} - (1-e_G)C$$

Recall from *Proposition* 2 that the utility of a "Good" borrower issuing straight long-term debt is

$$U_G^{LT} = x + c - \frac{1}{f + (1-f)\theta}$$

Then, a callable debt satisfying feasibility will dominate the straight long-term debt if $U_G^{callable} > U_G^{LT}$, i.e., if

$$e_G \frac{1 - f(1-e_G)C}{f e_G + (1-f)\theta} + (1-e_G)C < \frac{1}{f + (1-f)\theta}$$

Manipulating this inequality we get that it will be true if

$$C < 1$$

Which violates the incentive compatibility constraint above. Hence, there does not exist a feasible callable debt that dominates a straight short or long term debt.

□

Lemma 9 (Date-zero equilibrium under pooling)**.**

In a date-zero equilibrium contract in which both borrower types invest we have $\phi^* = 0$ *and* (D^*, F^*) *is characterized by*

- $D^* = qx$;
- $F^* = \frac{1-[fe_G+(1-f)]D^*}{f(1-e_G)}$;

as long as $\theta \geqslant \frac{1-\left[f^d(fe_G+(1-f))+f(1-e_G)\right]x}{[fe_G+(1-f)](1-f^d)x}$.

Proof.

From *Lemma* 5 we concluded that the date-zero equilibrium of this game must maximize the utility of a type-G borrower. Notice that this maximization program subject to date-zero investors zero-profit condition, feasibility and the anticipation of the equilibrium played at $t = 1$ is identical to the planner's problem if

- $D = z_{0,1} = qx$;
- $F = z_{0,2}$;

Hence, the date-zero equilibrium when we have pooling at the investment stage comes directly from *Lemma* 1.

□

C. Baseline Model Proofs

C.1. Proof of *Proposition* 1

Proof.

From *Lemma 2* we get that

$$U_G^{nc}(y^*, M^*) = x + c - \frac{f + (1-f)\theta(x+c)}{f + (1-f)\theta}$$

To check when the pooling contingent solution is preferred we need verify in which case the contingent planner's utility is greater than the non-contingent one. That is, if

$$U_G^c(K_c^*) > U_G^{nc}(y^*, M^*)$$

Let $\underline{\mathrm{m}}$ be such that $\frac{\partial U_G^c(K_c^*, \underline{\mathrm{m}})}{\partial m} = 0$. In that case, it must be true that $qx < 1$, for any $m > \underline{\mathrm{m}}$.

From the inequality above we must have

$$(1-e_G)\left[x - \frac{1 - [fe_G + (1-f)]qx}{f(1-e_G)}\right] > x - \frac{f + (1-f)\theta(x+c)}{f + (1-f)\theta}$$

Thus, taking $m \to \infty$ and $c \to 0$, the inequality above becomes

$$x - \frac{1 - (1-f)\theta x}{f} > x - \frac{f + (1-f)\theta x}{f + (1-f)\theta}$$

which leads us to the following quadratic inequality

$$(1-f)^2 x\theta^2 + (1-f)[2fx - 1]\theta - f(1-f) > 0$$

The roots of the "equation" above are then

$$\theta_1 = \frac{-(2fx-1) - \sqrt{(2fx-1)^2 + 4f(1-f)x}}{2(1-f)x} < 0$$

and

$$\theta_2 = \frac{-(2fx-1)+\sqrt{(2fx-1)^2+4f(1-f)x}}{2(1-f)x}$$

Claim. $\theta_2 < \frac{1}{x}$

To check it, we verify if

$$\frac{-(2fx-1)+\sqrt{(2fx-1)^2+4f(1-f)x}}{2(1-f)x} < \frac{1}{x}$$

which simplifies to

$$x(1-f^2)(x-1) > 0$$

This is always true given that $x > 1$, and $0 < f < 1$.

Therefore, we can conclude that $\exists \underline{\mathrm{m}} \in (1,\infty)$ and $\hat{\theta}_{\underline{\mathrm{m}}}$ solving $U_G^c(K_c^*) = U_G^{nc}(y^*, M^*)$ such that $\hat{\theta}_{\underline{\mathrm{m}}} = \frac{1}{x}$. Hence, $\forall m > \underline{\mathrm{m}}$, $\exists \theta_m < \hat{\theta}_{\underline{\mathrm{m}}}$ solving $U_G^c(K_c^*) = U_G^{nc}(y^*, M^*)$ and such that $U_G^c(K_c^*) > U_G^{nc}(y^*, M^*)$ for $\theta_m < \theta < \frac{1}{x}$.

□

C.2. Proof of *Proposition* 2

Proof.

Suppose the pooling equilibrium contract is such that it induces $W^*(d) = 0$ at $t = 1$. Then, from the zero profit condition of date-zero investors at $t = 0$, we have

$$[f + (1-f)\theta]F = 1$$

Thus,

$$F = \frac{1}{f + (1-f)\theta}$$

and, therefore, the utility of the type-G borrower will be

$$U_G(W(d) = 0) = x + c - \frac{1}{f + (1-f)\theta}$$

Now, I move on to the case in which withdrawals are induced in equilibrium. Recall from *Lemma* 3 that withdrawals will happen at $t = 1$ after a credit downgrade only if $\frac{F}{D} \leqslant \frac{1}{q}$. I will show that there always exists a feasible pooling contract where: (i) date-zero investors are withdrawing at $t = 1$ after a credit downgrade; and (ii) it dominates the one in which withdrawals do not happen.

Again, from date-zero investors zero profit condition at $t = 0$ we have

$$(f e_G + (1-f))D + f(1-e_G)F = 1$$

that is,

$$F = \frac{1 - [f e_G + (1-f)]D}{f(1-e_G)}$$

The utility of the "Good" borrower will then be

$$U_G(W(d) = D) = x + c - e_G \frac{D}{q} - (1-e_G)\frac{1 - [f e_G + (1-f)]D}{f(1-e_G)}$$

Therefore, the question is:

Is there a value of D satisfying:

1. $D > qF$, where $F = \frac{1-[f e_G+(1-f)]D}{f(1-e_G)}$, guaranteeing that (i) date-zero investors are indeed withdrawing at $t = 1$; and (ii) F is such that they are not making losses in expectation;

2. $DS \leqslant x$, where $S = \frac{1}{q}$, guaranteeing that the withdrawal from date-zero investors would not lead to default;

3. $D \leqslant 1$, otherwise this puttable debt would be suboptimal;

4. $e_G \frac{D}{q} + (1 - e_G)\frac{1-[fe_G+(1-f)]D}{f(1-e_G)} < \frac{1}{f+(1-f)\theta}$, guaranteeing that indeed a pooling equilibrium inducing withdrawals is dominant, i.e., $U_G(W(d) = D) > U_G(W(d) = 0)$.

Moreover, this comparison between both pooling equilibria, with and without withdrawals, is valid only if the pooling equilibrium without withdrawals is feasible. Meaning that, the long term competitive rate of return has to be less or equal than x. That is, $\frac{1}{f+(1-f)\theta} < x$. Therefore, we assume this condition holds and then I can verify whether or not all conditions $1-4$ above are valid.

Condition (1) implies that

$$D > \frac{q}{f(1-e_G) + q[fe_G + (1-f)]} \equiv D_1$$

whereas, condition (4) requires that

$$D > \frac{q(1-f)\theta}{q[fe_G + (1-f)] - fe_G} \equiv D_4$$

Claim. $D_4 \leqslant D_1$. Thus, if that is true, then condition (4) would be irrelevant. Hence, notice that $D_4 \leqslant D_1$ if

$$(1-f)\theta\{f(1-e_G) + q[fe_G + (1-f)]\} \leqslant q[fe_G + (1-f)] - fe_G$$

that is, if

$$f(1-f)\theta \leqslant \{q[fe_G + (1-f)] - fe_G\}[1 - (1-f)\theta]$$

Given that $e_G = \frac{1-f}{m-f}$, the inequality above simplifies to

$$(m-f)f\theta \leqslant (qm-f)[1-(1-f)\theta]$$

Additionally, given that $q = f^d + (1 - f^d)\theta$ and that $f^d = \frac{f}{m}$ the inequality above further simplifies to

$$(1-f)\theta\left[(m-f)\theta-(m+f)\right] \leqslant 0$$

which is always true. Therefore, condition (4) is irrelevant and we can keep checking the other 3 conditions. Notice that, if $\frac{D_1}{q} \leqslant x$ and $D_1 \leqslant 1$, then by continuity there must exist a feasible D satisfying all conditions $1-4$.

We start by checking whether $\frac{D_1}{q} \leqslant x$. Given that we assumed that $\frac{1}{f+(1-f)\theta} < x$ to satisfy the feasibility constraint of a pooling equilibrium without withdrawals, it is enough to check if $\frac{D_1}{q} \leqslant \frac{1}{f+(1-f)\theta}$. That is, if

$$\frac{1}{f(1-e_G)+q\left[fe_G+(1-f)\right]} \leqslant \frac{1}{f+(1-f)\theta}$$

which leads to

$$fe_G(1-q) \leqslant (1-f)(q-\theta)$$

Again, given that $e_G = \frac{1-f}{m-f}$ the inequality above simplifies to

$$f(1-\theta) \leqslant m(q-\theta)$$

Additionally, given that $q = f^d + (1 - f^d)\theta$ and that $f^d = \frac{f}{m}$ the inequality above further simplifies to

$$f(1-\theta) \leqslant f(1-\theta)$$

which is obviously always true. We remain to check if $D_1 \leqslant 1$. That is, if

$$\frac{q}{f(1-e_G)+q\left[fe_G+(1-f)\right]} \leqslant 1$$

Notice that the above inequality can be simplified to

$$qf \leqslant f$$

which is always true given that $q \leqslant 1$.

Hence, we can conclude that, given a pooling date-zero contract, there will always exist a feasible pair (D, F) such that date-zero investors are withdrawing at $t = 1$ after a credit downgrade, the level of withdrawals does not lead to default and that this contract dominates any date-zero pooling contract that induces no withdrawal at $t = 1$.

□

C.3. Proposition 2 - Example

The following example highlights the contingent outcomes and its allocative improvement relative to straight debt.

Example 1. *Consider a risk-neutral monopolistic bank at* $t = 0$ *in need for funds to take a risky investment opportunity (loan) costing* \$1. *If the investment is of good quality* (G)*, it returns a cash flow of* $x = \$1.5$ *at* $t = 2$ *with certainty, whereas if it is of bad quality* (B)*, it will return* $x = \$1.5$ *at* $t = 2$ *with probability* $\theta = 0.5$ *and* \$0*, otherwise. The banker is assumed to enjoy a private rent of* $\alpha = 0.1$ *if he retains control of the loan until* $t = 2$*, and is privately informed about the project's quality, while risk-neutral investors assign a prior probability* $f = 0.5$ *to the investment being of type G and* $1 - f = 0.5$ *to type B. An exogenous and non-contractible shock hit investors' priors regarding the project's quality at* $t = 1$.[21] *In particular, this shock will either be a "credit upgrade" or a "downgrade", that is, denote by* $f^u = 1$ *and* $f^d = 0.25$ *the posterior probabilities that the loan quality is of type G conditional on an upgrade or a downgrade, respectively. Notice that, after an upgrade, investors are certain that the loan is of good quality, therefore any security traded on the future cash flow will be risk-less. On the other hand, after a credit downgrade, the posterior probability* (q) *that*

[21] This could be interpreted as some soft information regarding the bank's loans. Alternatively, this could be driven by some private liquidity shock faced by investors which correlates to bank's asset quality. Or any economic shock affecting bank's loans in which verification is costly.

the project will in fact payout at $t = 2$ *is* $q = f^d + (1 - f^d)\theta = 0.25 + 0.75 * 0.5 = 0.625$. *Therefore, any dollar claim traded at* $t = 1$ *after a credit downgrade will be priced at* $\frac{1}{q} = 1.6$. *The bank would be facing disintermediation and potentially losing any control rents, as in Diamond (1991), if it is funded by short-term debt. To see this, notice that any short-term debt must promise at least the gross risk-free rate to investors, here assumed to be* 1. *Thus, in case of a credit downgrade, the bank would be forced to raise, at* $t = 1$, *the dollar promised to initial investors. However, as argued above, the price of this dollar claim would be* 1.6, *which is greater than what the loan generates at* $t = 2$, *hence, the bank would be in technical default. This implies that the required short-term rate that guarantees investors participation will be* 1.125.[22] *We can then conclude that, if funded with short-term debt, a bank holding a good loan would get, in expectation,* $U_G^{st} = \frac{f - f^d}{f(1-f^d)} * (1.5 - 1.125 + 0.1) \approx 0.316$. *Alternatively, the "good" bank could avoid disintermediation by issuing a long-term debt. Notice that the price of a dollar claim from a long-term debt is exactly the reciprocal of the probability of project success evaluated at* $t = 0$. *That is, in order to raise one dollar by issuing a long-term debt, the bank would have to promise* $\frac{1}{f+(1-f)\theta} = \frac{4}{3}$ *at* $t = 2$. *Thus, a "good" bank would get* $U_G^{lt} = 1.5 - \frac{4}{3} + 0.1 \approx 0.266$ *if it issued a long-term debt to finance the loan. Interestingly, even though it would be potentially facing disintermediation, the "good" bank still prefers to issue short-term over the long-term debt, but, can it do better? Even though the bank cannot contract on the signal (upgrade or downgrade), it could still delegate the maturity choice of its liability structure to investors by issuing a (time) deposit contract, and consequently avoiding disintermediation, even after a credit downgrade, by adjusting the short-term yield paid to depositors. Consider a deposit contract which pays* (i) \$0.9375 *at* $t = 1$ *if investors withdraw it;* (ii) \$1.125 *at* $t = 2$ *if they do not withdraw it.*[23] *Therefore, by avoiding disintermediation and guaranteeing investors participation, the "good" bank*

[22] Investors would not break-even if they are disintermediating the bank after a credit downgrade and getting only the dollar back after an upgrade. Therefore, the required short-term rate (sr) that guarantees investors participation is the one satisfying $\left[f\frac{f^d(1-f)}{f(1-f^d)} + (1-f)\right] * 1.5q + f\frac{f-f^d}{f(1-f^d)}sr = 1$ that is, $sr = 1.125$.. Where $\left[f\frac{f^d(1-f)}{f(1-f^d)} + (1-f)\right]$ is the ex-ante probability of observing a downgrade at $t = 1$ and $f\frac{f-f^d}{f(1-f^d)}$ is the ex-ante probability of observing an upgrade at $t = 1$.

[23] Notice that these deposit terms guarantee that investors are at their participation constraint. If banks are pooling in equilibrium, the probability, at $t = 0$, that investors will observe a credit downgrade at $t = 1$ will be $p_d = f\frac{f^d(1-f)}{f(1-f^d} + (1-f) = 0.666$, whereas the ex-ante probability that they will observe an upgrade at $t = 1$ is $1 - p_d = 0.333$. Hence, $0.666 * 0.9375 + 0.333 * 1.125 = 1$.

is getting $U_G^{dep} = 0.1 + \frac{f-f^d}{f(1-f^d)} * (1.5 - 1.125) = 0.35$, *which is better than issuing either short or long-term debt.*

C.4. Proof of Proposition 3

Proof. Notice that, in case of withdrawals after a downgrade, the bank will have to pay $\rho v + (1 - \rho)$ to date-zero investors. Given that $\rho = \frac{1-D^*}{1-v}$, we have that

$$\rho v + (1 - \rho) = D^*$$

which matches the withdrawal payment from *lemma* 9.

In the non-withdrawal case, the bank owes $\rho\Upsilon + (1 - \rho)$ to date-zero investors. Hence, given that $\Upsilon = \frac{1-[fe_G+(1-f)]v}{f(1-e_g)}$ we have that

$$\rho\Upsilon + (1 - \rho) = \frac{\rho - [fe_G + (1 - f)](\rho + D^* - 1)}{f(1 - e_G)} + (1 - \rho) = \frac{1 - [fe_G + (1 - f)]D^*}{f(1 - e_g)} = F^*$$

which also matches the non-withdrawal payment from *lemma* 9. We just need to make sure the withdrawal constraint is satisfied, that is

$$v \geqslant q\Upsilon$$

□

C.5. Proof of Corollary 1

Proof. Notice that $\frac{\partial D^*}{\partial f} > 0$, $\frac{\partial D^*}{\partial \theta} > 0$, $\frac{\partial D^*}{\partial x} > 0$. Hence, the result follows immediately from the fact that $\rho \propto -D^*$. □

D. Comparative Statics and Extensions

D.1. Proof of *Proposition* 4

Proof. (*a*) Notice that the separating menu dominates the pooling menu if and only if

$$U_G^{sep} > U_G^{pool}$$

That is,

$$x - \frac{f + (1-f)\theta(x+c)}{f + (1-f)\theta} > (1-e_G)\left[x - \frac{1 - [f e_G + (1-f)]qx}{f(1-e_G)}\right]$$

which implies that

$$\frac{(1-f)\theta}{f + (1-f)\theta}c < x - \frac{f + (1-f)\theta x}{f + (1-f)\theta} - (1-e_G)\left[x - \frac{1 - [f e_G + (1-f)]qx}{f(1-e_G)}\right]$$

that is, if $c < \hat{c}$. Given that the expected duration conditional on separation is equal to 2, and the expected duration conditional on pooling is strictly less than 2, we have our result.

(*b*) Similarly, the separating menu dominates the pooling menu if and only if $f < \hat{f}$. Therefore, we remain to show that the expected duration under the pooling menu is increasing in f.

For simplicity, take the case where $qx \geqslant 1$. Recall from *Proposition* 9 that $D^*_{pool} = 1$ and that $F^*_{pool} = 1$. Plugging it back into the expected duration we get

$$\mathbb{E}\left[MacD_{pool}\right] = [f e_G + (1-f)] + 2f(1-e_G)$$

Note that $\frac{\partial e_G}{\partial f} = -\frac{(m-1)}{(m-f)^2}$. Hence,

$$\frac{\partial \mathbb{E}\left[MacD_{pool}\right]}{\partial f} = e_G - \frac{f(m-1)}{(m-f)^2} - 1 + 2(1-e_G) + \frac{2f(m-1)}{(m-f)^2} = 1 - e_G + \frac{f(m-1)}{(m-f)^2} > 0$$

□

Lemma 10. *Let certificates of deposits and savings deposits have a Macaulay duration of 2 and 1, respectively. Then, in equilibrium, borrowers' liability structure would have a duration that decreases in the credit rating (f) and in the intensity of the adverse selection problem (θ).*

Proof. Follows immediately from *propositions* 4 and *corollary* 1. □

D.2. Proof of *Propostion* 5

Proof. From *Lemma* 6 we know that the feasibility condition for a separating menu is given by

$$\theta \leqslant \frac{f(x-1)}{(1-f)c} \equiv \underline{\theta}$$

Moreover, the cost of capital for the high-quality borrower in a separating menu F^*_{sep} is given by

$$F^*_{sep} = \frac{f + (1-f)\theta(x+c)}{f + (1-f)\theta}$$

which is increasing in θ. On the other hand, from *lemma* 9 we know that the feasibility condition for a pooling menu is given by

$$\theta \geqslant \frac{1 - \left[f^d(f e_G + (1-f)) + f(1-e_G)\right]x}{[f e_G + (1-f)](1-f^d)x} \equiv \bar{\theta}$$

Moreover, the cost of capital for the high-quality borrower in a pooling menu F^*_{pool} is given by

$$F^*_{pool} = \frac{1 - [f e_G + (1-f)]D^*}{f(1-e_G)}$$

which is weakly decreasing in θ given that $D^* = qx$ and that $q = f^d + (1-f^d)\theta$. Hence, we can conclude that the cost of capital for the high-quality borrower is hump-shaped in θ and

that, if $\underline{\theta} < \bar{\theta}$ the market breaks down for intermediate values of θ. We remain to show how the cost of capital varies with m, the signal precision.

Consider the case in which the pooling menu is the date-zero equilibrium. The cost of capital for the high-quality borrower in a pooling menu F^*_{pool} is given by

$$F^*_{pool} = \frac{1 - [f e_G + (1-f)]qx}{f(1-e_G)}$$

Therefore, differentiating F^*_{pool} with respect to m we get

$$\frac{\partial F^*_{pool}}{\partial m} = f(1-qx)\frac{\partial e_G}{\partial m} - f(1-e_G)[f e_G + (1-f)]x\frac{\partial q}{\partial m}$$

The first term of the RHS captures how an increase in the signal precision (m) reduces the cost of capital by its effect on the probability of a credit downgrade, while the second term captures the effect on the date-one adverse selection problem conditional on a credit downgrade, thus increasing the overall cost of capital. To check which force dominates we can expand even further the expression above and notice that

$$\frac{\partial F^*_{pool}}{\partial m} \propto (1-f)f\frac{x(1-\theta)}{m} - (1-qx)$$

Notice that, the second term $-(1-qx)$ is negative, whereas the first term $f(1-f)\frac{x(1-\theta)}{m}$ is hump-shaped in f and that

$$lim_{f\to 0} f(1-f) = 0$$

and

$$lim_{f\to 1} f(1-f) = 0$$

Therefore, $\frac{\partial F^*_{pool}}{\partial m}$ is positive only for intermediate values of f. □

D.3. Proof of *Proposition* 6

Proof. From *proposition* 1 we know that for low values of θ the date-zero equilibrium is separating. That is, the low-quality borrower is issuing long-term debt with face value $\phi^{ast} = 1-\theta(x+c-F^*_{sep})$ which is decreasing in θ. This implies that the monetary profit of a low-quality borrower increases in θ for low values of θ.

For higher values of θ, the date-zero equilibrium is pooling at the investment stage. In this case, the monetary profit of a low-quality borrower will be zero. This happens because the date-zero equilibrium is pooling and borrowers are issuing a mix of savings and certificates of deposits with a withdrawal payment $D^* = qx$. Therefore, since a low-quality borrower is always downgraded at $t = 1$, investors will withdraw, forcing the borrower to raise additional capital at $t = 1$ with a face value equal to $\frac{qx}{q} = x$.

□

D.4. Proof of *Proposition* 7

Proof. Note that, conditional on withdrawals after a downgrade, the borrower's rollover cost at $t = 1$ when $r = d$ will be $\frac{D+\gamma}{q} = x$. Moreover, after a credit upgrade, the borrower's payment to investors at $t = 2$ will be $F + \gamma = \frac{1-[fe_G+(1-f)]qx}{f(1-e_G)}$. That is, they are identical to the optimality condition of *lemma* 9.

Hence, we just need to verify for the withdrawal constraint. That is

$$D \geqslant qF$$

or, equivalently

$$qx - \gamma \geqslant q\frac{(1-\gamma)-[fe_G+(1-f)](qx-\gamma)}{f(1-e_G)}$$

that is

$$\gamma \leqslant \frac{q\left[q(f e_G + (1-f)) + f(1-e_G)x - 1\right]}{q\left[f e_G + (1-f)\right] + f(1-e_G) - q} \equiv \gamma^*$$

□

D.5. Proof of *Proposition* 8

Proof. We just need to guarantee that the sophisticated investor is optimally withdrawing when $r = d$ and not withdrawing when $r = u$.

Suppose $r = d$ at $t = 1$ and the sophisticated investor tries to renegotiate the terms of the contract with the unsophisticated. The attempt to renegotiate would immediately be met by withdrawals, forcing the sophisticated to then withdraw its deposits in its entirety to repay the unsophisticated investors.

Alternatively, suppose that $r = u$. The sophisticated, knowing that any attempt to renegotiate would be met by withdrawals from the unsophisticated, could try to renegotiate with the unsophisticated, and then also renegotiate with the original borrower a profit split, given that, after a credit downgrade the rollover is cheap. This attempt would not render extra profits to the sophisticated investor as he has sold equity to the unsophisticated.

Therefore, given that the sophisticated would never profit from renegotiation attempts, he has proper incentives to optimally withdraw the deposits. □

D.6. Proof of *Proposition* 9

Proof. First, notice that the low-quality borrower utility under the FDIC policy is given by

$$U_B^{FDIC} = \theta\left(x + c - \frac{(1-\gamma)qx + \rho}{q} - \gamma F^* + \rho\right)$$

Therefore, given the *Optimality Condition*, we get that

$$U_B^{FDIC} = \theta c = U_B^{baseline}$$

We remain to check for the high-quality bank's utility. That is,

$$U_G^{FDIC} = e_G\left(x + c - \frac{(1-\gamma)qx + \rho}{q} - \gamma F^* + \sigma\right) + (1 - e_G)(x + c - F^*)$$

that is,

$$U_G^{FDIC} = e_G c + (1 - e_G)(x + c - F^*) = U_G^{baseline}$$

□

D.7. Variable Investment

Suppose that the payoffs from investing in the risky project are scalable with the size of the investment (I). Hence, let us assume that the risky investment scales in size $x(I)I$, that $x'(\hat{I}) = 0$ for some $\hat{I} > 0$, and that $x''(I) < 0$. The next proposition reconciles the empirical evidence that larger banks rely relatively less on CDs than checkings and savings deposits as their main source of funding.

Proposition 10. *The investment size that maximizes the profits of the high-quality borrower increases in f and x.*

Proof. Let's consider the baseline model where banks are pooling in equilibrium. The high-quality bank's utility is given by

$$U_G = (1 - e_G)(x(I)I - FI)$$

The first order condition gives us

$$\frac{\partial U_G}{\partial I} = x'(I^*)I^* + x(I^*) - F = 0$$

Where F is the optimal non-withdrawal payment from *lemma* 9. Hence, for a given I, whenever x increases we have that $x(I) - F$ increases. Therefore, I^* has to increase in order to satisfy the first-order condition given that $x''(I) < 0$.

Similarly, whenever f increases, F decreases, which also implies that I has to increase to satisfy the first-order condition.

□

An increase in safety f or project profitability x increases the marginal revenue of the high-quality bank, which incentivizes it to invest more up to a point where the marginal revenue equals the marginal cost.

D.8. Safe Banks

Consider the case in which $qx > 1$. From *lemma* 9 we know that banks will issue traditional savings deposits as they are extremely safe and do not need the insurance provided by CDs.

Proposition 11 (Balance Sheet Expansion)**.** *Borrowers will optimally issue a quantity $Q = qx$ of traditional savings deposits, invest the excess capital raised $I = Q-1$ into risk-free securities and issue a credit default swap (CDS) which pays I to investors in case of loan default at $t = 2$, and investors are required to pay a premium $P = \frac{(1-q_0)I}{q_0}$ to the bank in case of loan success, where q_0 is the date-zero probability of loan success.*

Proof. Note that the utility of the high-quality borrower can be written as

$$U_G^{expansion} = e_G\left(x + c - \frac{Q}{q} + (Q-1) + \frac{(1-q_0)(Q-1)}{q_0}\right) + (1-e_G)\left(c + x - Q + (Q-1) + \frac{(1-q_0)(Q-1)}{q_0}\right)$$

Differentiating $U_G^{expansion}$ with respect to Q we get

$$\frac{\partial U_G^{expansion}}{\partial Q} = e_G\left(1 + \frac{(1-q_0)}{q_0} - \frac{1}{q}\right) + (1-e_G)\left(\frac{1-q_0}{q_0}\right) = \frac{1-q_0}{q_0} - e_G\frac{1-q}{q} > 0$$

Hence, we want to maximize Q. Therefore, it must be true that $Q = qx$ in order to respect the solvency constraint qx. We just need to check that investors buying the credit default swap are breaking even in expectation. That is, let the premium paid to the bank in case of loan success be $P = \frac{(1-q_0)(Q-1)}{q_0}$, then

$$(1-q_0)(Q-1)-q_0\frac{(1-q_0)(Q-1)}{q_0}=0$$

□

This result highlights the fact that larger banks are primarily funded with traditional savings deposits. When bank loans are safe and profitable relative to the adverse selection problem $qx > 1$, the bank has excess capacity in its balance sheet to make risky loans and still be able to sell insurance against them. This happens because it is cheap for high-quality borrowers to sell insurance given that they are certain that their loans will not default at $t = 2$, and therefore they can earn the insurance premium without facing the risk of delivering the insurance payment.