Understanding the Role of Certificates of Deposits in Bank Finance*

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Abstract

Banks have superior information on asset quality, while bank investors update their beliefs based on non-contractible signals over time. In this environment, I show that Certificates of Deposits (CDs) arise as part of the optimal liability structure in bank finance. Essentially, CDs allow for maturity transformation while mitigating solvency risks in case of early withdrawals. In other words, they are structured to correlate investors' withdrawal decisions with asset quality. This, in turn, minimizes the cross-subsidies from high- to low-quality banks, as it 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 banks rely more on CD funding relative to other types of deposits, as suggested by their balance sheet data.

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

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

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1. Introduction

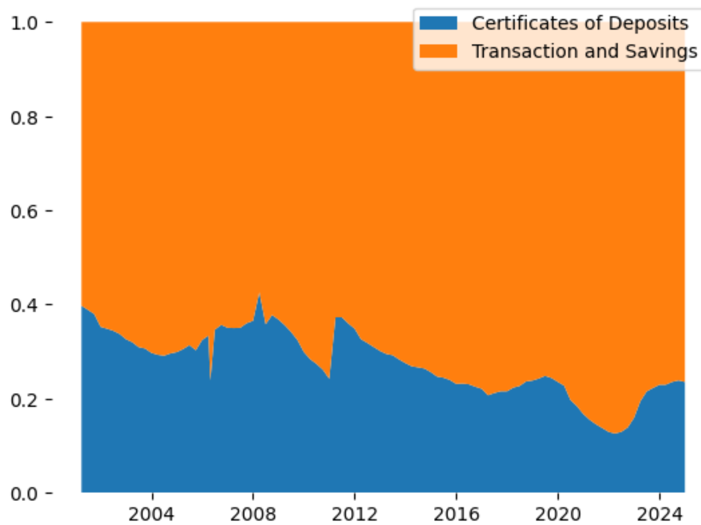
Certificates of deposits (CD) are an important source of funding for U.S. commercial banks (Figure 1). However, their determinants are still understudied relative to traditional demand deposits. In this paper, I dig deeper into why banks issue CD contracts by proposing a novel credit risk hedging story. In particular, I show that CDs arise as the optimal contract in a dynamic adverse selection model *à la* Diamond (1991) in which: (i) banks are better informed about the credit risk of their assets, (ii) depositors update their beliefs about asset quality based on non-contractible signals over time, and (iii) negative news can render the bank insolvent depending on the contract issued.[1] In the model, the withdrawal penalties that are present in CD contracts protect banks against future negative shocks that induce substantial withdrawals.

Specifically, the model features a monopolistic bank that needs funding at date-zero in order to invest in an illiquid asset (loan). The bank can be either a high- or a low-quality bank. In particular, a high-quality bank has access to a low-risk (high expected return) investment opportunity, while a low-quality bank has access to a high-risk (low expected return) investment opportunity. At date-zero, the market infers the credit quality of a bank's assets based on public information about it (date-zero prior), while the bank has private information about the quality of its investment. Thus, based on its private information and the market inference about its credit quality, the bank chooses the form of funding it will receive from investors at date-zero. At date-one, investors obtain a non-contractible noisy private signal about the bank's investment, which makes them revise their initial assessment about the bank's credit quality (date-one posterior).[2] After updating their beliefs, they decide whether or not to withdraw funds, if this is contractually allowed. If funds are withdrawn, the bank raises external capital to meet demand, which is priced conditionally on the updated credit information that market investors have. At date-two, the asset cash-flow realizes and contractual payments are made.

[1]These primitives are consistent the empirical evidence that banks are opaque institutions (Morgan (2002)) and present a significant cross-sectional variation in credit risk exposure (Begenau et al. (2015)).

[2]In general, the high-quality bank receives a positive update. However, with some positive probability, investors might make the wrong inference (negative news) and the high-quality bank can be revised down from its date-zero perceived quality. A low-quality bank always receives a negative update.

Figure 1: Aggregate Breakdown by Deposit Type



Notes: Data source: Reports of Condition and Income ("Call Reports") for U.S. domestic banks, compiled by the Wharton Research Data Services (WRDS). The blue region refers to the proportion of certificates of deposits (dollar value) to total deposits (dollar value) in the aggregate of U.S. commercial banks for each quarter from 2001 to 2024.

In light of the model described above, I show that CD funding emerges when investors perceive that the bank has low credit quality (high credit risk) at the funding stage. The reason lies in the trade-offs and incentives that arise given the combination of the information asymmetry present at date-zero and the information update at date-one, and here is why: (i) a high-quality bank knows that it is undervalued at date-zero, so it wants some short-term rollover exposure to capture the favorable repricing after positive updates at date-one; (ii) issuing only short-term debt (or standard demand deposits) would leave it vulnerable to insolvency if negative updates occur.[3] CD contracts resolve this trade-off since they permit exposure to short-term rollover while protecting solvency via withdrawal penalties on date-zero investors. Consequently, high-quality banks, when heavily under-priced at date-zero, prefer CDs.[4] In equilib-

[3]This argument relies on depositor attentiveness and *de facto* exposure to credit risk. Recently, it has been argued that depositors, especially uninsured depositors, are sophisticated enough and respond quickly to credit quality deterioration (see for example, Iyer and Puri (2012), Iyer et al. (2016), Egan et al. (2017), Pérignon et al. (2018), Artavanis et al. (2022), Chen et al. (2022), Cipriani et al. (2024), Martin et al. (2024)).

[4]In the model, when the date-zero beliefs about credit quality are high enough, banks issue standard demand deposits as there are no solvency concerns in the future even after negative news.

rium, low-quality banks also issue CDs, otherwise they would not obtain date-zero funding. A key comparative static follows: a mean-preserving increase is asset credit spreads shifts funding toward CDs relative to standard demand deposits. Equivalently, riskier banks issue more CDs.

An illustrative example of the model is the Citigroup case during the subprime crisis. Between 2005 and 2007, Citibank (part of Citigroup Inc.) aggressively expanded its exposure to subprime and other high-risk mortgage assets.[5] Through the lenses of the model, this period of market expansion via subprime lending can be viewed as a period of high credit risk (low credit quality) relative to the counterfactual that the bank had not invested in riskier assets to expand its business. Hence, as suggested by the model, Citibank should finance this expansion through a liability structure that relied relatively more on CD funding. This is exactly what its balance sheet data show. During this period (2005-2007), in which the Citigroup credit default swap (CDS) spread between the 5-year and the 10-year CDS premiums substantially increased, Citigroup's reliance on CD funding increased from 17% to 31% of total deposits (Figure 2).[6]

In line with this anecdotal evidence, I expand the analysis and show that the quantity of risk is positively correlated with the reliance on CD funding for the entire cross-section of U.S. commercial banks and for the aggregate time series in the past ten years. Starting from 2015, following Basel III reforms, U.S. commercial banks are required to report a granular estimate of their risk positions, that is, loans and assets are now classified in many more risk-categories, with risk-weights that range from 0% to 1250%, reflecting into a more accurate and transparent estimate of their risk-taking behavior relative to the previous years. Then, I construct the ratio of risk-weighted assets to total assets to proxy for credit risk and estimate that a 10p.p. increase in the ratio of risk-weighted assets to total assets is associated with a 1.86p.p. increase in the

[5]The bank's investment and structured finance divisions securitized large volumes of subprime mortgages, often holding substantial senior tranches on its own balance sheet. Citigroup's exposure came both directly, through the purchase and retention of mortgage-related securities, and indirectly, via liquidity guarantees and off-balance-sheet conduits. By 2007, its total subprime-related exposure exceeded $40 billion, reflecting a major concentration of risk in assets tied to deteriorating U.S. housing markets (Wilmarth Jr (2014)).

[6]Other major U.S. banks such as the JPMorgan and the Bank of America (BofA) presented similar patterns during the subprime crisis. Graphs in the data appendix.

Figure 2: Citigroup CD funding and CDS spreads

Notes: Data on the reliance of CD funding relative to total deposits are from the Reports of Condition and Income (”Call Reports”) compiled by the Wharton Research Data Services (WRDS). Data on the 5-year and the 10-year credit default swap premiums are from Bloomberg. CDS quotes are obtained from the last trading day of each quarter. The increase in the spread between the 5-year CDS and the 10-year CDS reflects a higher perception of short-term credit risk relative to the long-term risk.

reliance on CD funding relative to total deposits. This suggests that the predicted positive relation between credit risk and CDs holds in the data beyond the anecdote.

So far, I have argued that a simple dynamic adverse selection model with exogenous learning over time is able to rationalize why banks holding riskier asset portfolios rely more on CD funding relative to other types of deposits. However, the model has some important caveats. As mentioned earlier, the model requires investor sophistication, as it assumes depositor attentiveness at the interim stage.[7] In reality, this might not always be true, at least for a sizable fraction of depositors, especially insured depositors (e.g., Drechsler et al. (2017), Drechsler et al. (2021)). Therefore, to accommodate this empirical observation and study how it affects banks liabilities, I enrich the baseline model by allowing for depositor heterogeneity regarding their level of “sophistication”. In particular, I assume that a fraction of the bank’s date-zero supply of capital comes from “unsophisticated” investors. That is, investors who are unable (or

[7] As is the case of other supply side stories of demandable debt such as Calomiris and Kahn (1991) and Koufopoulos et al. (2024).

unwilling) to observe the date-one credit signal.[8]

With this modification, I break down the analysis into two steps in order to gain clarity about the trade-offs banks face when raising funds from a heterogeneous base of investors. In the first step, I study how banks cost of capital is affected by the presence of some unsophisticated investors. Then, in the second step, I tie this type of investor to an FDIC deposit insurance scheme.

For the first part, notice that when banks need to raise funds from a mass of unsophisticated investors, their cost of capital could ultimately increase due to two reasons: (i) in the model, depositors must break even in expectation; and (ii) they would require higher short-term deposit rates, as they do not observe credit risk updates and therefore cannot make optimal withdrawal decisions, thus facing greater risks. Interestingly, I show that when this fraction of unsophisticated capital is relatively small, banks can achieve the same level of efficiency implied by the baseline model, that is, when one-hundred percent of their date-zero supply of capital is sophisticated. To achieve the same level of efficiency, i.e., the same cost of capital, banks issue CD contracts with a steeper term structure to sophisticated investors.[9] In some sense, sophisticated investors are "absorbing" the inefficiency caused by lack of information of the unsophisticated by facing larger withdrawal penalties. That is, the combination of higher short-term rates promised to the unsophisticated with the smaller short-term payments, in case of withdrawals, promised to the sophisticated provides banks with the same insurance level they could obtain in the baseline model.

However, banks would penalize withdrawals up to a certain limit. That is, if banks try to impose an extremely large penalty, the insurance provided by CD contracts loses its effect. The reason is twofold: (i) again, in the model, investors must break even in expectation. Therefore, a

[8]It could be costly to monitor banks' credit quality, and therefore, the insurance element of CD contracts would not provide the appropriate incentives for depositors to monitor.

[9]Although I do not empirically test it, the model is predicting that the term structure of CD rates is steeper for banks that rely relatively more on unsophisticated depositors. Some studies have shown how CD interest rates correlate with other bank characteristics. For instance, it has been shown that CD interest rates correlate with credit (e.g., Keeley (1990), Ellis and Flannery (1992)) and maturity transformation risk (Fleckenstein and Longstaff (2024)).

very large withdrawal penalty must be associated with a high promised long-term rate; and (*ii*) when the promised long-term return is too high relative to the withdrawal penalty, investors will not withdraw their deposits even after negative updates on credit risk at date-one. Hence, we can see a connection between the proportion of unsophisticated capital that banks rely on and their cost of capital. Intuitively, as we move away from a sophisticated source of capital, we are not able to use the penalty structure provided by CD contracts to insure against credit risk. Empirically, though, the presence of an unsophisticated base of depositors is usually associated with a lower cost of funding (Drechsler et al. (2017)). Therefore, to connect with this fact, I tie the supply of unsophisticated capital to deposit insurance.

That is, when the fraction of unsophisticated investors is relatively high, I show that a FDIC insurance policy can restore efficiency.[10] In the model, banks are charged an insurance premium based on its credit risk assessment at date-one, the noisy signal on credit risk that sophisticated (informed) investors receive. The collected premiums are then paid back to date-zero investors who still hold bank deposits in case of bank failure at date-two. Interestingly, if deposit insurance was underpriced, i.e., borne by outsiders instead of collected from banks, then the need to insure against credit risk through CD funding would diminish. Banks would increase their shares of traditional demand deposits relative to total deposits as the costs of insuring against negative shocks are being paid by outsiders, therefore decreasing banks cost of capital and increasing their profits.

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

[10]"The FDIC receives no appropriation from Congress, although it is backed by the full faith and credit of the U.S. government. Instead, the agency is funded by insurance premiums paid by banks and from interest earned on the FDIC's Deposit Insurance Fund, which is invested in U.S. government obligations. The banks' premiums depend on the size of the bank and bank regulators' assessment of the riskiness of the bank." More details can be found at https://www.brookings.edu/articles/how-does-deposit-insurance-work/. FDIC assessment rates can be found at https://www.fdic.gov/deposit-insurance-assessments/fdic-assessment-rates.

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 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)).

Related Literature

This paper is mostly related to the literature on the role of 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.[11] These models, however, are cast on the assumption that banks are illiquid at the interim date and have no access to external capital, which is not supported by recent empirical studies (e.g., Pérignon et al. (2018), Martin et al. (2024), Cipriani et al. (2024)). These studies have shown that banks facing runs generally raise money from other depositors, the Federal Home Loan Banks (FHLBs), and the Federal Reserve discount window.

Even when there is aggregate uncertainty at an interim stage due to information updates on asset quality, as is the case of my model, or in Jacklin and Bhattacharya (1988), the assumption of illiquidity gives rise to results that contradict empirical evidence. In particular, equity contracts are more efficient than certificates of deposits when volatility in asset return increases. This result stems from the fact that the contract choice is set to minimize consumers' risk against future liquidity shocks. Without external liquidity on an interim date, a highly volatile asset would induce investors to withdraw funds more often, thus interrupting projects with positive expected returns. If banks had access to external liquidity in these models, traditional demand deposits would be more efficient in mitigating depositors' liquidity risks.

Regarding the supply-side motivation for issuing CD contracts, there are several early works that relate CD issuance to the regulatory environment during the 1900s. In particular, Regu-

[11] See also Jacklin (1987); Chari and Jagannathan (1988); Goldstein and Pauzner (2005); Farhi et al. (2009). It is important to enphasize that these models, Diamond and Dybvig (1983) included, are about CDs and not standard demand deposits.

lation D and Regulation Q used to impose more stringent interest rate ceilings and reserve requirements on transaction and savings than on CD accounts. This set of policies induced banks to compete for market deposits using the less regulated CD contracts (e.g., Klein (1971), Cook (1978), Slovin and Sushka (1979)). Similarly, CD accounts, especially those with long maturity and large withdrawal penalties, receive differential treatment in the calculation of the Liquidity Coverage Ratio (LCR) as it does not enter into the denominator comprising an estimate of the total net cash outflows over a 30-day period. Hence, banks with LCRs close to the regulatory boundary could also be induced to issue long-term CD contracts.[12]

Compared to this paper, the closest supply-side story of CDs is that 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 banks, while the riskier ones rely on traditional deposits that may force them into liquidation. Using the Reports of Condition and Income (Call Reports), I show that the exact opposite holds in the data. That is, in the cross-section of banks, riskier ones rely more on CD funding relative to other types of deposits, which helps them prevent asset liquidation and stay solvent. This is in line with the evidence in Supera (2021), who shows that CD funding is positively correlated with Commercial and Industrial loans.

More broadly, this paper is also related to the literature on the coexistence of deposit-taking and long-term lending in dynamic asymmetric information models. Although Flannery (1986), Diamond (1991), and Diamond (1993) have highlighted the trade-offs between short- and long-term funding in asymmetric information models with exogenous learning, they have overlooked a potential role for deposits and in particular certificates of deposits. As argued, this has important qualitative and quantitative consequences given that CDs help high-quality banks share the deadweight risks of liquidation. In contrast, papers that have incorporated deposit-taking to long-term lending have often abstracted away the information friction from the contracting stage, or have taken deposit flows as given.

[12]This last point deserves further investigation. To the best of my knowledge, no work has ever tested whether stressed banks tend to issue more CDs relative to other demand deposits. It has been pointed out how difficult it is to estimate LCRs using balance sheet regulatory data (Cetina and Gleason (2015).

In Lucas and McDonald (1992), banks 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. In addition, they assume that the inflow/outflow of deposits is exogenous and is not part of the banks' optimal capital structure choice.[13] Therefore, without asymmetric information at the funding stage, the capital structure does not play a role in the sense discussed here. Stein (1998) studies a framework in which banks have private information on their assets in place. New loans are assumed to be riskless; therefore, again there would be no role for the capital structure 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. 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 describes the data and presents the empirical results. 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 consider a dynamic adverse selection model with exogenous learning as in Diamond (1991), and I apply it 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

[13] In Chu (1999), although the bank has private information about the quality of its loans at the funding stage, deposit inflows are assumed exogenously.

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 $t = 2$.[14] 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.[15] 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, i.e. $\theta x + c < 1 < x$, 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.

Incentives and Tradeoffs. There are two major tradeoffs in the model. First, the issuance of short-term debt or traditional demand deposits might render the bank insolvent at date-one, forcing it into costly liquidation and making it lose its control rent. To see this, note that: (i) any short-term debt must promise at least the risk-free rate of return back to investors, and (ii) conditional on a downgrade, the date-one probability of project success at date-two (q) is given by $q = f^d + (1 - f^d)\theta$. Thus, if $qx < 1$ the bank will default on it's short-term liability. This outcome is Pareto-dominated by the case in which the bank issues a certificate of deposit promising qx in case of withdrawal at date-one, since it would be able to raise funds to meet demand as $\frac{qx}{q} = x$, thus enjoying its private benefit of control $c > 0$.[16] Second, the high-quality

[14]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.

[15]This is the common prior.

[16]Of course, the long-term no-withdrawal return should compensate for the penalty imposed by withdrawal. However, such return would be equivalent to the required short-term return in case the bank issued traditional demand deposits. This happens because investors can recover at most qx by disintermediating the bank, which is

bank is undervalued from a date-zero perspective relative to the date-one belief update after investors receive the non-contractible signal about asset quality. Notice that (i) from a date-zero perspective, investors believe that the bank is a high-quality bank with probability f; (ii) conditional on observing an upgrade at date-one, investors believe that the bank is a high-quality bank with probability 1; and (iii) conditional on observing a downgrade at date-one, investors believe that the bank is a high-quality bank with probability f^d. Therefore, from a date-zero perspective, the high-quality bank expected credit rating at date-one $\mathbb{E}_{0,1}[f|G]$ is denoted by

$$\mathbb{E}_{0,1}[f|G] = e_G f^d + (1 - e_G) > f$$

Hence, a high-quality bank will have incentives to issue contracts with short-term exposure in order to profit from the expected favorable rollover pricing.

In light of the discussion above and before introducing the game and showing the equilibrium analysis, I derive the optimal mechanism and characterize the optimal allocation in this informed-principal (bank) framework.

2.1. Optimal Allocation

An informed-principal (bank) has the objective of (i) extracting all potential profits from the project that the agent (investor) finances; and (ii) minimizing the cross-subsidies it pays to the low-quality banks.[17] Hence, I solve the problem of a planner who seeks to maximize the expected profits of a high-quality bank, subject to incentive compatibility, feasibility, and participation constraints, achieving the Miyazaki-Wilson-Spence allocation. Generally, the planner can implement either a mechanism that pools both types at the investment stage or one that separates types at the investment stage. In the subsequent analysis, I restrict attention to optimal mechanisms that implement pooling at the investment stage for two reasons:

1. Even when separating mechanisms are considered, I show in the appendix that the pool-

identical to the withdrawal payment promised by the CD contract.

[17] An axiomatic foundation of the informed-principal problem can be seen in Myerson (1983).

ing mechanism dominates the separating one for a sizable region of parameters. The reason is straightforward. Recall that a high-quality bank is undervalued at date-zero with respect to belief updates at date-one. A menu that separates types at the investment stage is priced relative to investors' date-zero prior information on bank types, which prevents the high-quality bank from profiting from favorable expected date-one updates.

2. Alternatively, any mechanism that induces type separation at the investment stage requires that the menu offered provides cross-subsidies between contracts. In particular, since the low-quality bank has a negative NPV project, separation is only achieved if the menu offered by the planner contains a contract that pays the low-quality bank to stay out of the market. One could reason that it is much easier to structure banks that invest in negative NPV projects. Such rationale is derived from the "fake entrepreneur" reasoning outlined by Tirole (2010). Therefore, we could infer that they would "dominate" the market if they expected that such contracts would be offered in the first place. This would render such a menu infeasible, and separation to be unattainable. This analysis stems from the fact that such menus are generally not observed empirically.[18]

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 $t = 1$.

Pooling Mechanism. I now characterize the planner's allocation under pooling. 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 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 $t = 2$.

[18]An application of this argument can be seen in Bernhardt et al. (2020).

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 $z_{0,1} \geqslant qz_{0,2}$.[19]

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 planner's problem (PP) as follows:

$$\begin{aligned} \max_{K_c} \quad & U_G^c(K_c) && \text{(PP)} \\ \text{subject to:} \quad & \\ & \pi^c(K_c) \geqslant 0 && \text{(PC)} \\ & K_c \text{ is feasible} \end{aligned}$$

That is, the planner is maximizing the payoff of a high-quality bank subject to feasibility and investors' participation constraints, i.e, the planner is not making losses in expectation. *Lemma* 1 characterizes the contingent planner solution.

Assumption 1. The average project is positive NPV, that is, $\theta \geqslant \frac{1-\left[f^d(f e_G+(1-f))+f(1-e_G)\right]x}{[f e_G+(1-f)](1-f^d)x}$.

[19] 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.

Lemma 1. *[Miyazaki-Wilson-Spence Allocation]*

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

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

Proof. All proofs are in the Appendix. □

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 bank wants to reduce the adverse selection problem it faces by forcing the low-quality bank to pay the most they possibly can, while preventing the high-type from getting liquidated. This is achieved when banks raise capital at $t = 1$ after a downgrade to pay initial investors.

2.2. Implementation

Motivated by the discussion above, the notion of equilibrium is the Perfect Sequential Equilibrium (PSE) of Grossman and Perry (1986). Essentially, a PSE will be a Perfect Bayesian Equilibrium (PBE) satisfying a forward induction refinement, such as the *Intuitive Criterion* of Cho and Kreps (1987) or the *D1 Criterion* of Banks and Sobel (1987), with the additional constraint that off-equilibrium beliefs must be "credible" in the sense proposed by Grossman and Perry (1986).[20] Interestingly, because the low-quality bank is negative NPV and given the dynamic learning structure of the model, this refined equilibrium notion is shown to implement the planner's allocation discussed above as the unique equilibrium of the proposed game.[21]

[20] Mailath et al. (1993) proposes a similar restriction on off-equilibrium beliefs which they call "admissible" belies. In practice, whenever an off-equilibrium contract can strictly benefit both types of bank, investors assign posterior probabilities equal to their priors. Otherwise, the off-equilibrium beliefs are considered non-credible or non-admissible.

[21] Notice that this is not true in general. In a static asymmetric information setting, Bernhardt et al. (2022) have shown that this type of game generally admits multiple equilibria, even when we refine with forward induction

Date-zero contracts. At $t = 0$, the bank raises one dollar by issuing a deposit contract (D, F).[22] Formally, the bank demands a quantity of capital $I = 1$, chooses a $t = 1$ withdrawal payment D, a $t = 2$ non-withdrawal payment F. Then, if the contract is accepted, the bank invests in the risky asset and issues the deposit. On the other hand, if the menu is not accepted, the game ends immediately. In summary, a date-zero contract offered by the bank is a tuple $K_0 = (\{D, F\}; \{I\})$, upon which investors choose to accept it or not. Hence, denote by $\mathbb{K}_0 = K_0 \cup \{a\}$ the date-zero contract where, upon acceptance ($a = 1$), investors provide the borrower with an amount of capital $I = 1$, and receive the deposit (D, F).

Note that

1. The contract formulation is general enough. I am not imposing that the bank has to issue a CD contract. For instance,
   (a) A straight long-term debt is equivalent to $D = 0$ and $F > 0$;
   (b) A straight short-term debt is equivalent to $D > 0$ and $F = 0$;
   (c) A traditional demand deposit is equivalent to $D = F = 1$;
   (d) A CD contract is equivalent to $D > 0$ and $D < F$;
2. 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

concepts. The canonical paper micorfounding zero profits for investors in an informed principal framework is Nachman and Noe (1994), where borrowers post securities without a price, and the equilibrium price is determined by a competitive auction. Alternatively, Netzer and Scheuer (2014) and Diasakos and Koufopoulos (2018) propose 3-stage screening games and show that they implement the ex-ante efficient allocation for informed principal problems (Miyazaki-Wilson-Spence allocation).

[22] It could also be thought of a mix of savings and certificates of deposits.

$W(r)$, 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 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,

$$U_G(\mathbb{K}_0, K_1, W) \equiv x + c - e_G\left(\frac{F}{D}(D - W(d)) + W(d)S(d)\right) - (1 - e_G)\left(\frac{F}{D}(D - W(u)) - W(u)S(u)\right)$$

and a low-quality borrower gets

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

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 at $t = 0$ are

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

It is implicit that both types of banks are pooling in the equilibrium contract they offer. The low-type will always mimic the high-type bank, otherwise investors would not accept the contract offered by the former given that the low-quality project is negative NPV. 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

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

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. Thus, if they end up buying the short-term debt after a credit rating downgrade, their expected profits are defined as

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

Thus, 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 $S(d)W$. 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 bank's 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 Sequential Equilibrium (PSE). Moreover, given the dynamic setting, the 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 the bank is of type-G,

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

α_1 is updated by *Bayes' Rule* on the equilibrium path

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^* and an acceptance decision $a^* \in \{1, 0\}$ satisfying:

1. *Investors' Participation Constraint*: fix a date-zero menu K_0^*. Investors cannot make negative profits in expectation, i.e.,

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

2. *Belief consistency*: Denote by α_0 the date-zero investors' posterior that the bank is of type-G,

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

α_0 is updated by *Bayes' Rule* on the equilibrium path. Moreover, $\alpha_0 = \alpha_1$.

3. *Off-Equilibrium Belief Credibility*: Suppose that the date-zero offer K_0^*, inducing $\mathbb{K}_0^*$ and (K_1^*, W^*, δ^*), is an equilibrium contract. If there exists another offer $\tilde{K}_0$, inducing $\tilde{\mathbb{K}}_0$ and $(\tilde{K}_1, \tilde{W}, \tilde{\delta})$, such that

$$U_G(\tilde{\mathbb{K}}_0, \tilde{K}_1, \tilde{W}) > U_G(\mathbb{K}_0^*, K_1^*, W^*)$$

and

$$U_B(\tilde{\mathbb{K}}_0, \tilde{K}_1, \tilde{W}) < U_B(\mathbb{K}_0^*, K_1^*, W^*)$$

K_0^* is said to violate the off-equilibrium belief credibility. In addition, if there exist $\hat{K}_0$, inducing $\hat{\mathbb{K}}_0$ and $(\hat{K}_1, \hat{W}, \hat{\delta})$, such that

$$U_\tau(\hat{\mathbb{K}}_0, \hat{K}_1, \hat{W}) > U_\tau(\mathbb{K}_0^*, K_1^*, W^*), \quad \forall \tau \in \{B, G\}$$

then $\alpha_0 = \alpha_1 = f$.

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

A date-zero equilibrium then guarantees that the 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* 2 shows that deposit withdrawals will occur depending on the withdrawal payment D relative to the long-term payment F, accounting for the credit rating update at $t = 1$.

Lemma 2 (Date-One Equilibrium Withdrawals)**.**

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

1. $S^*(u) = 1$ *and* $W^*(u) = 0$ *if and only if* $F \geqslant D$*;*

2. $S^*(d) = \frac{1}{q}$ *and* $W^*(d) = 0$ *if and only if* $qF \geqslant D$*;*

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.

Corollary 1. $\delta^*(d) = 1$ *if and only if* (i) $r = d$ *and* (ii) $qF \leqslant D$ *and* $D > qx$*.*

As a corollary we obtain that liquidation will occur if and only if (i) there is a credit downgrade at date-one and (ii) the withdrawal payment is large enough to, at the same time, induce withdrawals and prevent the bank from raising the amount needed to meet demand.

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. We know that both types of banks will offer the same contract in equilibrium. Essentially, given that the low-quality bank has a negative NPV project, offering different contracts would convey information to investors, who therefore would not accept to put their money down. In addition, *Lemma* 3 guarantees that, in any date-zero equilibrium contract, the profits of the high-quality bank are maximized.

Lemma 3. *Any date-zero equilibrium contract* K_0*, inducing* $\mathbb{K}_0$*, maximizes the utility of a high-quality bank.*

Essentially, there are two types of PBE that pose threats to uniqueness. The first type refers to all PBE in which the low-quality bank is making positive monetary profits in expectation.

In this case, it is straightforward to see that such equilibria would violate the Intuitive Criterion, as there would be a deviation in which only the high-type profits from. The second, and more complicated one, refers to all PBE that is Pareto-dominated for all bank types. Usual forward-induction refinements tend to have difficulties eliminating them. However, the notion of "credible" or "admissible" off-equilibrium beliefs used here takes care of eliminating any Pareto-dominated contract. Intuitively, consider that $\alpha \geqslant f$ is an off-equilibrium belief for the high-type that would make the high-quality bank strictly prefer contract B to the equilibrium contract A. Even if the low-type bank also prefers B over A under α, off-equilibrium belief "credibility" or "admissibility", in the sense of Grossman and Perry (1986) or Mailath et al. (1993), requires that $\alpha_0 \geqslant f$, which bounds the set of off-equilibrium beliefs investors can have for the high-quality bank, thus breaking the equilibrium contract A. The difference imposed by off-equilibrium beliefs 'credibility' is that there is a link between the set of off-equilibrium beliefs one might have to calculate profitable deviations to the actual off-equilibrium beliefs one assumes in order to sustain the original equilibrium message (contract). Usual forward-induction refinements, such as the *Intuitive* and the *D1 Criterion*, allows for α_0 to be very low when $\alpha \geqslant f$ would induce profitable deviations for both types. Such disconnection is seen to be "non-credible". Hence, the equilibrium contract is derived from the following program:

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

$$\text{subject to:}$$

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

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

$$F \leqslant x$$

That is, the equilibrium contract is the one in which a high-quality bank gets maximum utility subject to investors' participation constraint, withdrawal constraint, and feasibility.

Given that investors learn about the project's quality dynamically, there will be a possibility of exploiting their belief updating, allowing banks achieve contingent outcomes without issuing contingent contracts. As shown in *Lemma* 2, investors will potentially have different behavior, at date-one, depending on the credit rating update they observe. The next result shows that this is precisely the case. In equilibrium, the deposit contract issued at $t = 0$ will always induce withdrawals, conditional on a downgrade, in order to minimize the cross-subsidies between high- and low-quality banks.

Proposition 1 (Straight Long-Term Debt Suboptimality)**.**

Suppose that $\mathbb{K}_0^*$ *is a date-zero equilibrium contract. Then, it must be true that* $\mathbb{K}_0^*$ *always induce withdrawals at* $t = 1$ *when a credit downgrade is observed. 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 CD contracts. By delegating the choice of the maturity structure to investors, high-quality banks will guarantee that whenever these depositors are actually facing low-quality banks, 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 CDs, banks 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 banks with extra profits given that they are undervalued at $t = 0$ (*Lemma* 4), whereas low-quality banks are overvalued.[23]

Lemma 4. *If* $qx < 1$*, straight debt does not implement the planner's solution.*

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* 1 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

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

allocation achieved through straight debt.[24] Intuitively, we could set the date-one calling price at qx, thus preventing disintermediation after a credit downgrade. Surprisingly, this would not 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* 5).

Lemma 5.

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

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* 1, 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. 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 achieves the ex-ante optimal allocation of Lemma 1.

Next, I present the ate-zero equilibrium that matches the planner solution from *Lemma* 1.

Proposition 2 (Date-zero equilibrium)**.**

In a date-zero equilibrium contract, (D^*, F^*) *are characterized by*

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

In equilibrium, the bank issues a CD contract whenever the average project is risky enough, that is, whenever $qx < 1$, and a traditional demand deposit whenever it is always solvent, even after a credit downgrade ($qx \geqslant 1$). An important question arises. How changes in mean-preserving risk-spreads shift bank's capital structure choices? I provide two answers for this question: (i) I show how the date-zero equilibrium contract of Proposition 2 changes as we have

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

a mean-preserving increase in the risk-spread of the project; and (ii) I study how banks implement the date-zero equilibrium as a mix of standard savings and certificates of deposits in light of a regulatory framework, then I show how this mix changes as we have a mean-preserving increase in the risk-spread of the project.

Consider two different risky assets A and A'. For asset A we have the pair risk-return to be (θ, x), while for asset A' we have (θ', x'). In addition, let $\theta > \theta'$ and $x < x'$ such that

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

that is, asset A' is riskier than asset A but has the same ex-ante expected return.

Proposition 3. *In general, a bank investing in asset A will issue standard demand deposits, while a bank investing in asset A' will issue CDs. That is, $q_A x > q_{A'} x'$.*

Intuitively, even though investors are risk-neutral and both projects have the same expected returns from a date-zero perspective, the riskier project is less liquid at date-one when downgraded compared to the safer project. From Proposition 2 we learned that banks with highly liquid projects at date-one after downgrades will be able to issue traditional demand deposits, while banks with relatively illiquid projects at date-one after downgrades have to issue CD contracts to insure against inefficient liquidation.

Empirically, though, banks charge a somewhat homogeneous set of penalty rates for CD contracts with different maturities, and most of the cross-sectional variation between banks and within banks over time comes from the proportion of CD funding relative to the total amount of deposits they raise. In addition, due to regulatory constraints, banks might be induced to charge higher withdrawal penalties than the ones theoretically prescribed by the model (Proposition 2).

In particular, following Basel III framework, banks are required to have the so called Liquidity Coverage Ratio at $Z\%$.[25] The LCR is determined by the ratio of the High-Quality Liquid Assets (HQLA) to a measure of expected Cash-Outflows over a 30-day period. Table 1 shows

[25] It is actually 100%. For the purposes of the argument I will keep it at a generic number Z in order to avoid confusion with the numerical examples.

an illustrative example extracted from Bank for International Settlements (BIS) (2013) of how different assets and liabilities are regarded in the calculation of the LCR.

Table 1: Illustrative Summary of the LCR

Stock of HQLA		Cash-Outflows	
Asset	Factor	Retail Deposits	Factor
Reserves	100%	Stable Retail Deposits	5%
Corporate Debt AA- or Higher	85%	Less Stable Retail Deposits	10%
Corporate Debt A+ and BBB-	50%	CDs with Residual Maturity (30+ Days)	0%

Notes: Following BIS definition, stable deposits, which usually receive a run-off factor of 5%, are the amount of the deposits that are fully insured by an effective deposit insurance scheme or by a public guarantee that provides equivalent protection. Less Stable deposits could include deposits that are not fully covered by an effective deposit insurance scheme or sovereign deposit guarantee, high-value deposits, deposits from sophisticated or high net worth individuals, deposits that can be withdrawn quickly (eg internet deposits) and foreign currency deposits, as determined by each jurisdiction.

Therefore, banks with high-risk assets on their balance sheets might raise a relatively higher proportion of CDs to comply with the LCR. Interestingly, the penalty size imposed on CD contracts become relevant for how CDs are treated in the LCR calculation. As Bank for International Settlements (BIS) (2013) states:

> "Cash outflows related to retail term deposits with a residual maturity or withdrawal notice period of greater than 30 days will be excluded from total expected cash outflows if... early withdrawal results in a significant penalty that is materially greater than the loss of interest."
>
> "If a bank allows a depositor to withdraw such deposits without applying the corresponding penalty..., the entire category of these funds would then have to be treated as demand deposits."

Motivated by these observations, I show how a mix of savings and certificates of deposit implements the date-zero equilibrium contract from Proposition 2 if we allow the withdrawal penalty for CD contracts to be higher than the one imposed before.

Proposition 4 (Mix of Savings and Certificates of Deposit)**.**

Consider the case where $qx < 1$. Let (D^*, F^*) be the CD parameters from Proposition 2. Consider a deposit contract which is composed by a mix of:

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

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

From Propositions 2 and 4 we can notice that the implementation of the planner's allocation can come from the size of the withdrawal penalty or from the proportion of certificates of deposits relative to savings deposits. Similar to Proposition 3, I show that a mean-preserving increase in the credit spreads of the risky project induces the bank to issue a higher proportion of CD contracts relative to standard demand deposits.

Corollary 2.

Consider the same assets A and A' from Proposition 3. The proportion of CDs to total deposits (ρ) issued by the bank is higher for asset A' than for asset A, $\rho_{A'} > \rho_A$.

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 of the assets of a bank, but in line with the empirical evidence in Supera (2021) showing a positive correlation between the reliance on CDs and commercial and industrial (C&I) loans. Using balance sheet data for the universe of U.S. commercial banks, I dig deeper into these predictions.

5. Empirical Results

In this section I explore the empirical predictions of the theoretical model.

5.1. Data Construction

I collect quarterly balance sheet data from the Reports of Condition and Income (Call Reports) for the universe of U.S. commercial banks from 2015 to 2024 provided by the Federal Financial Institutions Examination Council (FFIEC), compiled by the Wharton Research Data Services (WRDS). The variables of interest are: small time deposits (RCON6648 + RCONJ473); large time deposits (RCONJ474); total deposits (RCON2200); risk-weighted assets (RCOAA223); and total assets (RCON2170).[26]

The choice of focusing the empirical analysis on the period after 2014 is due to a regulatory shift on how banks now report their risk-weighted assets, the key variable of interest. Prior to 2015, banks used to report their risk-weighted assets following Basel I and Basel II accords, which contained much coarser categories of risk. In most cases, there were just 4 categories of risk: 0%, 20%, 50%, and 100%. Following Basel III accord, banks have to report their risk-weighted assets based on a much granular set of categories, ranging from 0% to 1250% for the most risky securities.[27] This reform allows us to have a more accurate estimate of the risk of a bank's assets.[28]

[26]RCON6648 refers to CD accounts below USD100k, while RCONJ473 to CD accounts between USD100k and USD250k. RCONJ474 refers to uninsured accounts above the USD250k limit. Risk-weighted assets are reported under RCFWA223 for large banks.

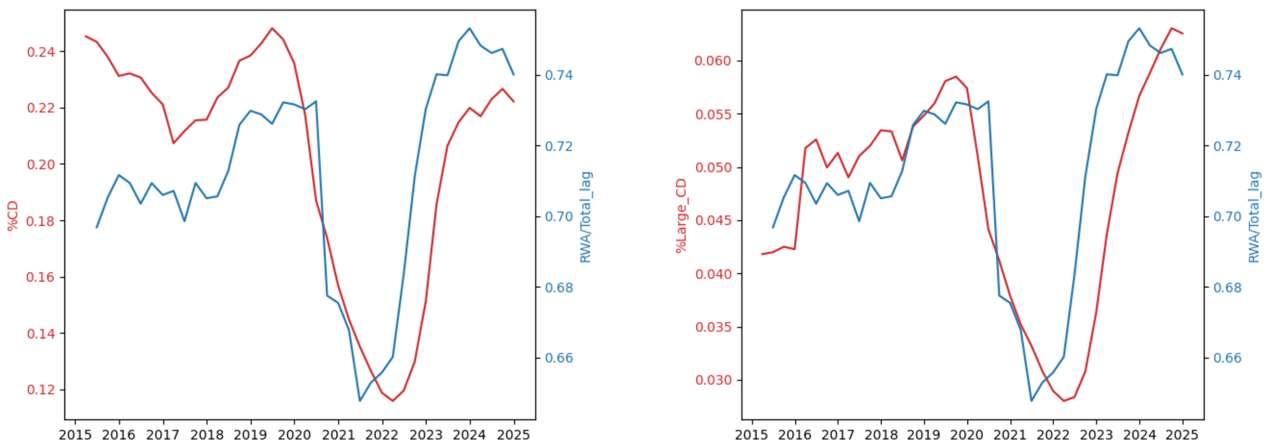
[27]A detailed outline of the risk-weighted categories can be seen at https://www.fdic.gov/system/files/2024-08/2018-12-rc-r-part-ii.pdf

[28]With a coarser set of risk-weight categories, a riskier bank could be perceived as safer. Take for example a bank *A* with all its assets under the 100% category. Then, consider a bank *B* with half of its assets under the 300% category and half under the 50% category. The true measure of risk for bank *B* should be 175%. However, if the riskier category is 100%, its perceived risk would be 75%, lower than that of bank *A*.

5.2. Empirical Evidence

I first show how the proportion of CD funding relative to total deposits correlate with the ratio of risk-weighted assets to total assets in the time series for the aggregate of U.S. commercial banks. The time series correlation is around 0.66 for the measure of CD accounts over total deposits, and even stronger for large CD accounts, 0.77 (Figure 3).

Figure 3: Aggregate Time Series Correlation Between CDs and Risk



Notes: For each quarter, data on the risk-weighted assets, total assets, dollar amount of CDs, and dollar amount of total deposits are aggregated for the universe of U.S. commercial banks. RWA/Total is the ratio of the aggregate risk-weighted assets over the aggregate of total assets, which is lagged one quarter. %CDs is the ratio of the aggregate dollar amount of CDs over the aggregate dollar amount of total deposits. The right panel computes the correlation for the proportion of large CD accounts over total deposits.

In addition, I provide cross-sectional evidence that is consistent with the model predictions (Table 2). For the baseline panel regression with just Bank id fixed effects, a 10p.p. increase in the ratio of risk weighted assets to total assets is associated with an increase of 1.86p.p. in the proportion of CD to total deposits and a 0.43p.p. in the proportion of large CD to total deposits. Results remain robust when we control for size, to capture differences in investment opportunities, and for the short-term risk-free rate (3-month tbill), to capture the outside options from the demand side.

Table 2: Regression Results

Independent Variables	CD/Total			Large CD/Total		
RWA/Total lag(1)	0.186***	0.150***	0.063***	0.043***	0.044***	0.022***
	(3.82)	(2.95)	(4.07)	(3.45)	(3.30)	(3.78)
Bank Size		−0.054***	0.007		0.008	-0.005
		(-2.58)	(0.87)		(1.20)	(-1.04)
3-month bill rate			0.005*			0.002***
			(1.65)			(2.82)
Bank FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	No	No	Yes	No	No	Yes
N	173006	173006	173006	173006	173006	173006

Notes: T-stats are reported in parenthesis and the standard errors are clustered at the bank id and the year levels. $***$ denotes $P-value < 0.01$. $**$ denotes $P-value < 0.05$. $*$ denotes $P-value < 0.1$. The measure of risk-weighted assets over total assets is lagged one quarter to capture the ex-ante measure of risk.

6. Model Extension

So far, I have argued that a simple dynamic adverse selection model with exogenous learning over time is able to rationalize why banks holding riskier asset portfolios rely more on CD funding relative to other types of deposits. As discussed, the model requires investor sophistication, as it assumes depositor attentiveness at the interim stage. In reality, this might not always be true, at least for a sizable fraction of depositors, especially insured depositors (e.g., Drechsler et al. (2017), Drechsler et al. (2021)). Therefore, to accommodate this empirical observation and study how it affects banks liabilities, I enrich the baseline model by allowing for depositor heterogeneity regarding their level of "sophistication". In particular, I assume that a fraction of the bank's date-zero supply of capital comes from "unsophisticated" investors. That is, investors who are unable or unwilling, due to costly monitoring, to observe the date-one credit signal. I show that this has important consequences for banks' capital structure and also that it has relevant policy implications, especially for deposit insurance.

6.1. Unsophisticated Depositors

Consider an alternative version of the baseline model in which, out of the date-zero dollar supply of capital the bank has access to, a fraction $(1-\gamma)$ of it comes from investors who observe the credit rating update at $t = 1$. The next result shows that, when the proportion of capital needed from sticky depositors γ is relatively small, a high-quality bank can achieve the same level of profits as in the baseline model.

Proposition 5. *There exists $\gamma^* \in (0, qx)$ such that, if $\gamma \leqslant \gamma^*$, the bank 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 banks' financial health. On the other hand, in the absence of any market solution, when the presence of unsophisticated investors is more pervasive in the banks' capital structure, the ability to have a state-contingent liability structure is hampered, which would cause an efficiency loss as high-quality banks profit level is diminished.

6.2. Policy Implication - FDIC Insurance

Proposition 5 showed that, when γ is large enough, there will be potential efficiency losses incurred by the high-quality bank. 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 premium from banks who get downgraded, then efficiency is restored.

Proposition 6. *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 Proposition 2 so that efficiency is restored if*

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

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

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 riskier 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, a 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. Baseline Model Proofs

Proof of Lemma 1.

Proof. Suppose (K_c^*) is a solution to (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. $z_{0,1}^* = min\{qx, 1\}$, 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,

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

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 maximize z_1^*, respecting the contingency constraint, that is, $z_{0,1}^* = \min\{qx, 1\}$. We just need to check for feasibility. From date-zero investors' (PC) we get

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

We need to make sure $z_{0,2} \leqslant x$ to satisfy feasibility. That is,

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

Hence, $z_{0,2}^*$ will be feasible if and only if

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

which is guaranteed by Assumption 1.

□

Proof of Lemma 2

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

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

Therefore, $W^*(u) = 0$ iff $F \geqslant D$.

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

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

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

□

Proof of Lemma 3.

Proof.

I will show that any date-zero equilibrium contract maximizes the utility of a type-G bank. 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),

$$\begin{aligned} \max_{I,D,L} \quad & U_G(\mathbb{K}_0, K_1, W) && \text{(GP)} \\ \text{subject to :} \quad & \\ & \pi_0(K_0) = 0 && \text{(PC)} \\ & F \leqslant x \end{aligned}$$

It must be true 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 $\mathbb{K}_0'$.

We need to analyze two cases.

1. If $U_B(\mathbb{K}_0', K_1', W') < U_B(\mathbb{K}_0^*, K_1^*, W^*)$, then $\mathbb{K}_0^*$ violates the Intuitive Criterion.
2. If $U_B(\mathbb{K}_0', K_1', W') \geqslant U_B(\mathbb{K}_0^*, K_1^*, W^*)$, then by the off-equilibrium belief "credibility" constraint, we must have that $\alpha_0(\mathbb{K}_0') \geqslant f$. This implies that $\mathbb{K}_0^*$ also violates the Intuitive Criterion.

Hence, $\mathbb{K}_0^*$ must maximize the utility of the type-G bank.

□

Proof of *Proposition* 1

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* 2 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

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

that is,

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

The utility of the ”Good” borrower will then be

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

Therefore, the question is:

Is there a value of D satisfying:

1. $D > qF$, where $F = \frac{1-[fe_G+(1-f)]D}{f(1-e_G)}$, 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

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

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

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

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

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

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 $t=1$.

□

Proposition 1 - 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* $t = 1$.[29] *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 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.[30] *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*

[29] 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.

[30] 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 $t = 1$.

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.*[31] *Therefore, by avoiding disintermediation and guaranteeing investors participation, the "good" bank 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.*

Proof of Lemma 4.

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, $U_G^{optimal} > U_G^{st}$. □

Proof of Lemma 5

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.

[31]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, $0.666 * 0.9375 + 0.333 * 1.125 = 1$.

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* 1 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.

□

Proof of Proposition 2

Proof.

From *Lemma* 3 we concluded that the date-zero equilibrium of this game must maximize the utility of a type-G borrower, guaranteeing uniqueness. 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

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

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

□

Proposition 3

Proof. Essentially, we need to show that $q_{A'}x' < q_A x$, which is the main determinant of the type of contract we get in equilibrium from Proposition 2.

That is, we need to check that

$$\left[\frac{f}{m} + \left(1 - \frac{f}{m}\right)\theta'\right]x' < \left[\frac{f}{m} + \left(1 - \frac{f}{m}\right)\theta\right]x$$

Thus, we need to verify if

$$fx' - fx + (m - f)\theta' x' < (m - f)\theta x \tag{1}$$

Notice that both projects have the same ex-ante expected return, i.e.,

$$[f + (1 - f)\theta']x' = [f + (1 - f)\theta]x \tag{2}$$

Hence, condition 1 can be rewritten as

$$\theta' x' - \theta x < 0 \tag{3}$$

In addition, given equation 2, we know that

$$\theta' x' - \theta x = f[(x - x') - (\theta x - \theta' x')] \tag{4}$$

So, suppose by way of contradiction that the inequality 3 does not hold, i.e., $\theta' x' > \theta x$. Then, given that $x' > x$ and $\theta > \theta'$, we must have that

$$x' - x > \theta'(x' - x) = \theta' x' - \theta' x > \theta' x' - \theta x$$

That is,

$$\theta x - \theta' x' > x - x'$$

which implies, by equation 4 that

$$\theta' x' - \theta x = f\left[(x - x') - (\theta x - \theta' x'\right] < 0$$

A contradiction. □

Proof of Proposition 4

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* 2.

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

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

which also matches the non-withdrawal payment from *Proposition* 2. We just need to make sure the withdrawal constraint is satisfied, that is

$$v \geqslant q\Upsilon$$

□

Proof of Corollary 2

Proof. Notice that $\frac{\partial \rho}{\partial D^*} < 0$. Given that $D^* = qx$, Proposition 3 shows that $D^*_{A'} < D^*_A$. The result follows immediately. □

Proof of *Proposition* 5

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 $F + \gamma = \frac{1-[f e_G + (1-f)]qx}{f(1-e_G)}$. That is, they are identical to the optimality condition of *Lemma* 2.

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

$$D \geqslant qF$$

or, equivalently

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

that is

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

□

Proof of *Proposition* 6

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,

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

□

B. Separating Mechanism

In this section I show the optimal allocation that separates bank types at the investment stage. Importantly, I demonstrate that there exists a parameter region in which the pooling allocation dominates the separating one.

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 separating menu is a pair (y, M) of: (i) cash transfer y to the bamk at $t = 0$; or (ii) a 1 dollar transfer to the bank 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 the high- from the low-quality bank, if it satisfies $y \geqslant \theta(x - M) + c$. 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:

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

Lemma 6 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.

Lemma 6 (Non-Contingent Planner Solution)**.**

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

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

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

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

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

and from the (PC) we have

$$f(M-1) = (1-f)\left[\theta(x-M) + c\right]$$

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

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

□

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 bank 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 bank incentive compatibility constraint of not investing — and therefore, pooling both types becomes efficient given that the cross subsidization decreases with θ, as shown by Proposition 7.

Proposition 7.

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.

From *Lemma 6* 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

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

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 $\theta_m < \theta < \frac{1}{x}$.

□

B.1. Implementation

To implement the separating allocation, we need to modify the game and allow for a menu of contracts. In particular, at $t = 0$, the bank raises one dollar by issuing a menu of contracts containing two different long-term debt with face values F and ϕ. Then, if and only if the menu is accepted, the bank chooses either to invest in the risky asset and issue the long-term debt with face value F within the proposed menu, or to invest in the riskless security and issue the long-term debt with face value ϕ. 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 $K_0 = (F;\phi)$, 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 debt F when the bank invests in the risky asset, or the debt ϕ.

Alternatively, we could still assume that the contract attached to the risky investment is a deposit contract (D,F). If the date-zero menu implements separation at the investment stage, date-zero investors' behavior would be very different. As I discuss next (*Lemma* 7), the short-term rate at date-one is always equal to 1 and date-zero investors do not withdraw their deposits in this case, which is unexplored in Diamond (1991).

Lemma 7 (*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 $S^*(d) = S^*(u) = 1$.

The 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 $W^*(u) = W^*(d) = 0$.

□

If investors anticipate separation, they correctly infer that only the high-quality bank 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 banks are issuing only long-term debt, upon which investors would have no withdrawal choice. *Lemma* 8 characterizes the menu of contracts that implements separation at the investment stage, i.e., the non-contingent planner's allocation.

Lemma 8 (Date-zero equilibrium under separation)**.**

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

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

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

Proof.

Follows immediately from *Lemma* 7 and noticing that this is exactly the non-contingent planner's problem solved in *Lemma 6* if we set $\phi = 1 - y$ and $F = M$.

□

Under a separation menu, *Lemma* 7 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 bank 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 the high-quality bank. 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. Next I provide comparative statics that focus on the shift between the pooling and the separating menu results.

B.2. 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 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

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

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

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

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 allow the high-type bank to match the duration between its assets and liabilities in expectation. The next result highlights how the expected duration varies with model parameters.[32]

Proposition 8.

The expected duration defined above is generally

(a) *weakly decreasing in the control rent c;*

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

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

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

That is,

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

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

which implies that

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

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, start with parameter values such that $qx=1$. Recall from *Lemma* 2 that $D^*_{pool}=1$ and that $F^*_{pool}=1$. Plugging it back into the expected duration we get

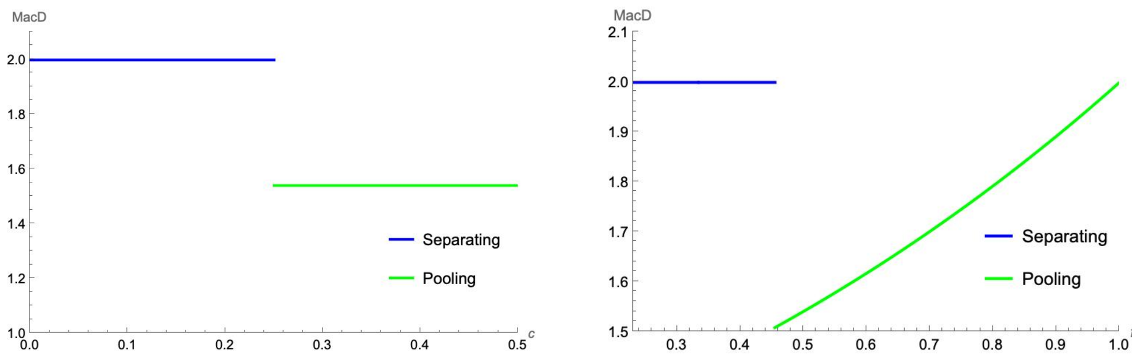
$$\mathbb{E}\Big[MacD_{pool}\Big]=[fe_G+(1-f)]+2f(1-e_G)$$

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

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

□

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 *Lemma* 2, 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 the high-quality bank prefers 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 4, panel (a)).



(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 4: Expected Duration

Also in contrast to Diamond (1991), I show that a high duration liability structure is a feature of low- or high-rated banks, while intermediate-rated banks 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 banks to underinvest and to have a liability structure duration that decreases in f for low-rated banks. 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 banks to issue straight long-term debt. In my model, the main concern is with overinvestment. Therefore, for low-rated banks, the adverse selection problem prevents any pooling equilibrium, which then forces low-quality banks 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 banks after a credit downgrade. Consequently, the duration increases in f for high-rated banks, as the increasing probability of a credit upgrade at $t = 1$ and project success overpower the front-loading terms of the deposit contracts ((Figure 4, 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* 9), an immediate consequence of *Corollary* 2.

Lemma 9. *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 *Proposition* 8 and *Corollary* 2. □

Proposition 9.

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

Proof. From *Lemma* 8 we know that the feasibility condition for a separating menu is given by

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

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* 2 we know that the feasibility condition for a pooling menu is given by

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

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

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

which is 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. 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

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

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

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

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. □

The first result contradicts classic intuition on ex-post moral hazard models (e.g., Calomiris and Kahn (1991)). In these models, it is expected that profits increase as we shrink the gap between low and high cash-flows.[33] 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.

The second result provides a rationale for opaqueness.[34] In general, it is expected that the signal precision (rating update) about types improves efficiency by reducing the cost of capital.[35] Intuitively, a more precise signal (higher m) reduces the chances that a high-type bank 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.[36] 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 banks (large f), but the probability of a credit downgrade is higher for lower-rated banks. Thus, this positive effect of

[33]Keeping the high cash flow fixed.

[34]Dang et al. (2017) argue that bank opaqueness can reduce firms' cost of funding by allowing risk-sharing between investors over time.

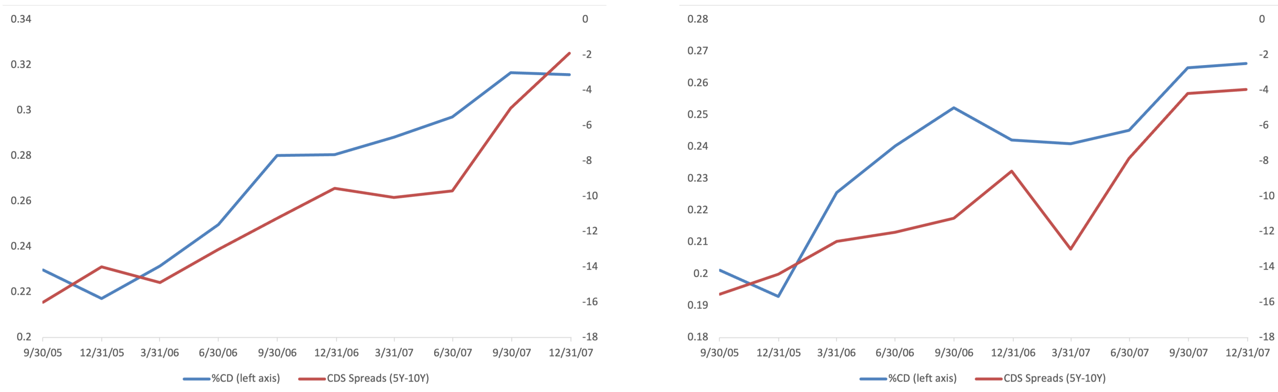
[35]The signal precision in the model is captured by m. If $m \to \infty$, the rating update is fully informative, while when $m = 1$, the update is uninformative.

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

a higher signal precision on the cost of capital will be relevant for intermediate-rated banks, whose profits can therefore increase with opaqueness (lower m).

C. Data Appendix

Figure 5: BofA (left panel) and JP Morgan - CD funding and CDS spreads



Notes: Data on the reliance of CD funding relative to total deposits are from the Reports of Condition and Income ("Call Reports") compiled by the Wharton Research Data Services (WRDS). Data on the 5-year and the 10-year credit default swap premiums are from Bloomberg. CDS quotes are obtained from the last trading day of each quarter. The increase in the spread between the 5-year CDS and the 10-year CDS reflects a higher perception of short-term credit risk relative to the long-term risk.