Collateralized Loan Obligations as Fire-Sale Insulation*

William Diamond
University of Wisconsin-Madison, wfdiamond@wisc.edu

Luigi Falasconi
Department of Economics, University of Pennsylvania, luigif@sas.upenn.edu

Chi (Clara) Xu
The Wharton School, University of Pennsylvania, chixu@wharton.upenn.edu

November 17, 2025

Abstract

We develop a model where CLOs are the optimal financial structure for securitizing assets that trade in illiquid markets. CLOs hold portfolios of risky loans, sell low-quality loans during crises, and finance themselves with safe, long-maturity debt. Banks that hold CLOs' safe debt are insulated from loan fire sales that could trigger a run if banks held risky loans directly. Unlike banks, CLOs with long-term financing can hold underperforming loans during a fire sale without triggering a run. Introducing CLOs to a bank-only financial system improves welfare and financial stability, but macroprudential regulation should also constrain CLOs' leverage.

Keywords: Collateralized Loan Obligations, Financial Intermediation, Safe Assets, Non-Bank Intermediation, Financial Stability

*We thank Mike Schwert and Tim Landvoigt whose input was very helpful in early stages of this project. We are also grateful to Dmitry Orlov, Lu Liu, Dean Corbae, Zhiguo He, and Simon Gervais for excellent comments. We also thank the Jacobs Levy Equity Management Center and the Wharton Finance Department for generously funding our research.

1 Introduction

Collateralized Loan Obligations (CLOs) are among the most novel and rapidly growing non-bank financial intermediaries in the United States. CLOs have expanded from roughly $200 billion in U.S. assets in 2006 to about $1 trillion in 2023. They now hold 60–70 percent[1] of all U.S. leveraged loans (Walsh et al., 2023), loans to risky firms that cannot qualify for a traditional bank loan. This is part of a broader trend since the 2008 crisis of risky financial intermediation moving outside of banks to less-regulated non-bank entities. Understanding the reasons behind this trend and how regulation should potentially respond to it is important for both academics and policymakers.

A positive theory that can explain the design of a non-bank intermediary like a CLO is useful for answering normative questions about its social value. Because there are stylized facts specific to CLOs that such a theory must explain, this paper develops a model of CLOs in particular instead of non-bank intermediaries as a whole. Even within the leveraged loan market, CLOs that hold loans are distinct from both bank and non-bank loan originators (Benmelech et al., 2012). As a result, theories of banking (Diamond, 1984; Gorton and Pennacchi, 1990) or securitization (DeMarzo, 2005) where informed originators have difficulty selling informationally-sensitive loans have difficulty explaining the purpose of CLOs.

This paper develops a theory of financial intermediation in which an institution structured like a CLO is the most efficient holder of loans that trade in an illiquid market. Our focus on market illiquidity is based on evidence (Elkamhi and Nozawa, 2022; Kundu, 2024) that leveraged loan prices are sensitive to fire sales, grounding our theory in realistic financial frictions. In our model, CLOs improves welfare and financial stability relative to a purely bank-based financial system, but welfare is further enhanced when CLO leverage is regulated.

Our model is consistent with a range of stylized facts about the structure of CLO balance sheets. Like other securitization vehicles, CLOs hold a diversified portfolio (or "pool") of

[1]Guggenheim Investments, S&P LCD, Bank of America, page 8, under figure titled "CLOs Are the Largest Leveraged Loan Investor."

risky loans against which they issue tranches of their own safer debt. Roughly two-thirds of a CLO's funding comes from a senior tranche of long-maturity debt with a AAA credit rating, often held by banks and insurance companies (DeMarco et al., 2020; Foley-Fisher et al., 2023). Unlike most other forms of securitization, CLOs actively buy and sell loans over time that other institutions originate. Additionally, CLOs are subject to financial covenants and cannot pay dividends to equity holders when a covenant is violated. To satisfy the most standard CLO covenants ("overcollateralization" and "interest coverage"), a CLO must hold a loan portfolio with a sufficiently high book value and which pays a sufficiently large amount of interest relative to the CLO's outstanding debt. However, CLO covenants rarely reference the market price of CLO assets, so the covenants can remain satisfied if loan prices crash.

Our model starts with a classic problem in financial intermediation: transforming risky, long-maturity, illiquid assets into safe, liquid, short-maturity liabilities. Intermediaries can issue short-maturity safe debt at a low interest rate R_d and raise additional funds from investors at a higher rate of return R_e in equity markets. This spread is due to investors' demand for holding safe, "money-like" assets (Krishnamurthy and Vissing-Jorgensen, 2012; Nagel, 2016; Van Binsbergen et al., 2022) such as bank deposits. Depositors have uncertainty about when they want to consume following Diamond and Dybvig (1983), so they must be given the option to withdraw their bank deposits. Because depositors are infinitely risk averse, they require being paid in full even in a possible bank run. The off-equilibrium threat of a run constrains the borrowing capacity of a deposit-taking bank. This results in a key problem in our model: an institution financed with runnable short-term debt is poorly suited to holding illiquid assets whose liquidation value during a run is low.

The solution is to divide the financial system into separate banks and CLOs. CLOs hold portfolios of risky, long-term loans, and issue safe, long-term debt. Banks hold enough liquid reserves to pay withdrawing depositors outside of a run and then hold the safe debt issued by CLOs to maturity. This results in "fire-sale insulation," where a fire sale of a loan held by a CLO does not precipitate a run on a bank. This effectively divides the

task of transforming illiquid, risky loans into safe, liquid deposits across bank and CLO balance sheets. Banks engage in maturity transformation, issuing short-maturity deposits and holding risk-free long-maturity CLO debt. CLOs, in turn, have assets and liabilities of the same maturity as each other but that differ in their safety and liquidity (Diamond, 2020). CLOs hold long-maturity risky assets that may experience fire sales, while issuing long-maturity safe liabilities that do not experience fire sales in equilibrium. CLO debt has a higher liquidation value during a possible bank run than the loans the CLO holds.

In the model, CLOs face a crucial choice of whether to sell poorly performing loans during a crisis or to hold the loans to maturity. A CLO that commits to selling bad loans before they default is able to repay a greater quantity of risk-free debt than a CLO that holds bad loans to maturity. However, the loan market is illiquid during crises, so loans can only be sold at depressed prices (Shleifer and Vishny, 2011; Dávila and Korinek, 2018). CLOs trade off the cost of liquidating poorly-performing loans at unattractive fire sale prices against the benefit of issuing greater quantities of safe debt ex ante (Stein, 2012; Hanson et al., 2015; Luck and Schempp, 2023). In equilibrium, CLOs are indifferent between liquidating loans and holding them to maturity, and this condition pins down the size of the fire-sale discount.

The behavior of CLOs in our model is empirically realistic. In good states, CLOs generate sufficient income to pay interest to debt holders and distribute dividends to equity holders. In bad states, when financial covenants become binding in practice, CLOs suspend dividend payments. During a financial crisis, CLOs sell their worst-performing loans and use the proceeds to repay part of their debt, as documented empirically (Elkamhi and Nozawa, 2022; Kundu, 2024). However, the long-term funding of CLOs insulates them from the risk of a run during a crisis. CLOs still earn high returns on investment (Cordell et al., 2021) by waiting for asset prices to recover after a crisis. Banks, in contrast, hold the risk-free long-term debt of CLOs to maturity and have no need to sell. Because banks hold safe assets that are not sold during a crisis instead of holding risky loans directly, they are insulated from the impact of loan fire sales that could otherwise trigger a run.

We compare the equilibrium of a financial system with CLOs to a traditional system where deposit-issuing banks lend directly to firms. Compared to a traditional banking system, the market value of a loan is strictly higher in a system with CLOs. This occurs because the same loan can safely back a greater quantity of risk-free debt when held by a CLO than when held by a run-prone bank. If loan prices were to fall during a crisis, a CLO could safely become mark-to-market insolvent as long as the loan's future cash flows were enough to pay the CLO's debt. A bank, in contrast, would be at risk of a run during a loan price crash if the market value of its loan portfolio were not enough to repay its existing deposits. To avoid runs, such a bank would have to rely less on low-yield risk-free debt financing and more on more expensive equity financing than a CLO that held the same loans.

In addition, because a CLO finds it more attractive to hold an illiquid loan to maturity than a bank does, the financial system with CLOs experiences smaller fire-sales in a crisis than a traditional banking system. In either financial system, banks or CLOs must be indifferent in equilibrium between selling a bad loan or holding it to maturity. If the bank finds holding a loan less attractive than a CLO, it must also get a worse fire-sale discount when selling to sustain this indifference. CLOs therefore improve financial stability by reducing fire-sale quantities. In our model, introducing CLOs to a traditional banking system is welfare improving. While our model is consistent with the empirical finding (Kundu, 2023; Elkamhi and Nozawa, 2022) that CLOs engage in fire sales of underperforming loans, it also shows that these fire sales would be worse in a financial system without CLOs.

Next, we show that a social planner would further improve welfare by regulating CLOs' fire sales. When choosing to sell or hold a loan, a CLO does not internalize the price impact of its trade. A social planner that does account for this price impact would want a CLO to sell strictly less than it would choose in in an unregulated equilibrium. Our model implies that CLOs are beneficial, but macroprudential regulation of CLO risk-taking is also beneficial.

We perform a simple calibration to quantify the impact of introducing CLOs to a financial system. We match the return on CLOs' equity and safe debt to estimates from Cordell et al.

(2021), CLO leverage to the contractual terms of new CLOs, the impact of CLO fire-sales to Elkamhi and Nozawa (2022), and returns on CLO assets to an index of leveraged loan market returns. We compare a financial system with CLOs to one with only banks, one with buy-and-hold securitization, and one with optimally regulated CLOs. CLOs increase utilitarian welfare by 0.7% above a traditional banking system. Optimal regulation of CLOs further raises welfare by 0.2% and reduces CLOs' fire sale quantities by more than half.

Finally, we present a dynamic, quantitative model of CLO portfolio choice where CLOs choose to sell risky loans in bad times, as in our theory. Here, CLOs dynamically rebalance a portfolio of leveraged loans subject to realistic financial covenants constraining their dividend payments and can possibly default on their debt. While the model allows for CLOs to "gamble for resurrection" by taking risks when default is likely, CLOs choose to reduce their risk taking both when their individual leverage is high and in an overall financial crisis.

Relation to Literature Our paper provides a unified theoretical explanation of CLO design. Except for Xu (2023)'s model of portfolio rebalancing, research on CLOs has been almost entirely empirical. One strand shows that financial covenants trigger fire sales of illiquid loans (Kundu, 2023, 2024; Elkamhi and Nozawa, 2022; Loumioti and Vasvari, 2019). Another measures the returns on both CLOs asset and liabilities, finding that issuing low-return safe debt explains CLOs' high return on equity (Cordell et al., 2021; Elkamhi et al., 2024; Griffin and Nickerson, 2023). A third documents that CLOs provide cheaper credit than banks (Shivdasani and Wang, 2011; Nadauld and Weisbach, 2012; Bord and Santos, 2015) and studies their credit supply dynamics (Bhardwaj et al., 2025; Fleckenstein et al., 2020). In our model, covenants and the sale of bad loans enable CLOs to issue large quantities of risk-free debt, which in turn expands their lending capacity and makes lending less cyclical. Our theory provides a unified explanation for multiple strands of empirical evidence.

Our paper connects the theoretical literature explaining the structure of financial intermediaries to modern non-bank intermediation. Models with information and monitoring frictions have been used to explain the structure of banks (Diamond, 1984; Gorton and Pen-

nacchi, 1990; Dang et al., 2017; Diamond and Rajan, 2001) and securitization (DeMarzo, 2005). (Benmelech et al., 2012) empirically finds that such frictions are weaker for CLOs, since CLOs hold portions of syndicated loans they do not originate. In our model, which is motivated by the market for leveraged loans where CLOs are active, illiquidity arises from trading frictions in secondary markets. In our model, CLOs insulate run-prone banks from illiquid loans (Chodorow-Reich et al., 2021; Hanson et al., 2015), reversing Diamond and Rajan (2001)'s result that deposits optimally fund illiquid assets and helping to explain the role of credit chains in non-bank lending (He and Li, 2022).

Finally, our model provides a normative framework to compare systems with and without CLOs and to analyze CLO regulation. Bank regulation (Buchak et al., 2018; Irani et al., 2021), bailout expectations (Falasconi, 2025), and central bank policy (Diamond et al., 2024; Acharya and Rajan, 2024) have pushed lending off of bank balance sheets, fueling the rise of CLOs and other non-bank lenders (Xu, 2025; Acharya et al., 2024). Because CLOs solve a fundamental economic problem in our model, we can analyze the regulation of CLOs without presupposing that they are an ad hoc regulatory arbitrage. CLOs improve welfare relative to a financial system with banks alone, but there is also reason to regulate CLOs.

2 Motivating Facts

This section presents stylized empirical facts about CLOs. We use a database from Semeris Documents that provides detailed information about the contractual structure ("indentures") of CLOs. We also reference existing facts in the literature.

Fact 1: CLOs raise the majority of their funding in the form of long-maturity AAA debt, and banks are the largest investors in AAA CLO debt. In our database of CLO indentures, the average CLO raises 63.1% of its initial funding by issuing debt with a AAA credit rating. The remaining funding comes from a mix of equity financing and more junior debt securities, which have lower credit ratings and pay higher interest rates than the

AAA tranche. The average maturity of the AAA debt issued by CLOs in our dataset is 12.36 years. CLO indentures often include a "weighted-average life" restriction that sets a maximum on the maturity of the loans they hold, ensuring only modest maturity mismatch between the assets and liabilities of CLOs.

DeMarco et al. (2020) provides summary statistics on the investors who funded CLOs in 2020. The largest investors in the AAA debt of CLOs are banks, which own 28% of all AAA CLO debt observed in their sample. Other large investors include pensions, insurance companies, "other financial institutions" (including bank holding companies), and mutual funds. Ninety-seven percent of banks' investments in CLOs are in the safest AAA tranches.

Fact 2: CLOs are the largest investors in the leveraged-loan market and actively re-balance their loan holdings over time. Leveraged loans refer to the riskier segment of the market for corporate loans, akin to junk bonds. The LSTA Leveraged Loan Index, which tracks this market, had $1.4 trillion of assets in 2024. CLOs in 2024 owned $1.3 trillion ($1 trillion in the U.S.) in leveraged loans and tend to own 65–70% of all outstanding leveraged loans (Walsh et al., 2023).

Unlike traditional securitization vehicles, CLOs trade their loan holdings over time. In our database, the median CLO is given five years during which it can actively re-balance its loan holdings before it must hold the portfolio to maturity. In a traditional securitization, a fixed pool of assets produces cash flows that are then divided among investors. CLOs, in contrast, trade their leveraged loans in a somewhat liquid secondary market. They tend to sell loans after severe drops in loan performance. Several empirical papers have shown that these sales by CLOs result in "fire-sale discounts" that push the prices of sold loans temporarily below their fundamental value (Elkamhi and Nozawa, 2022; Kundu, 2023, 2024). Complementing this "micro" evidence of leverage loan fire-sale discounts, Figure 1 shows the performance of the overall leveraged-loan market since 2000. After the 2008 and 2020 crises, crashes in loan prices were followed by rapid recoveries, so investors who stayed invested during "macro" episodes of systemic fire sales were able to profit *ex post*.

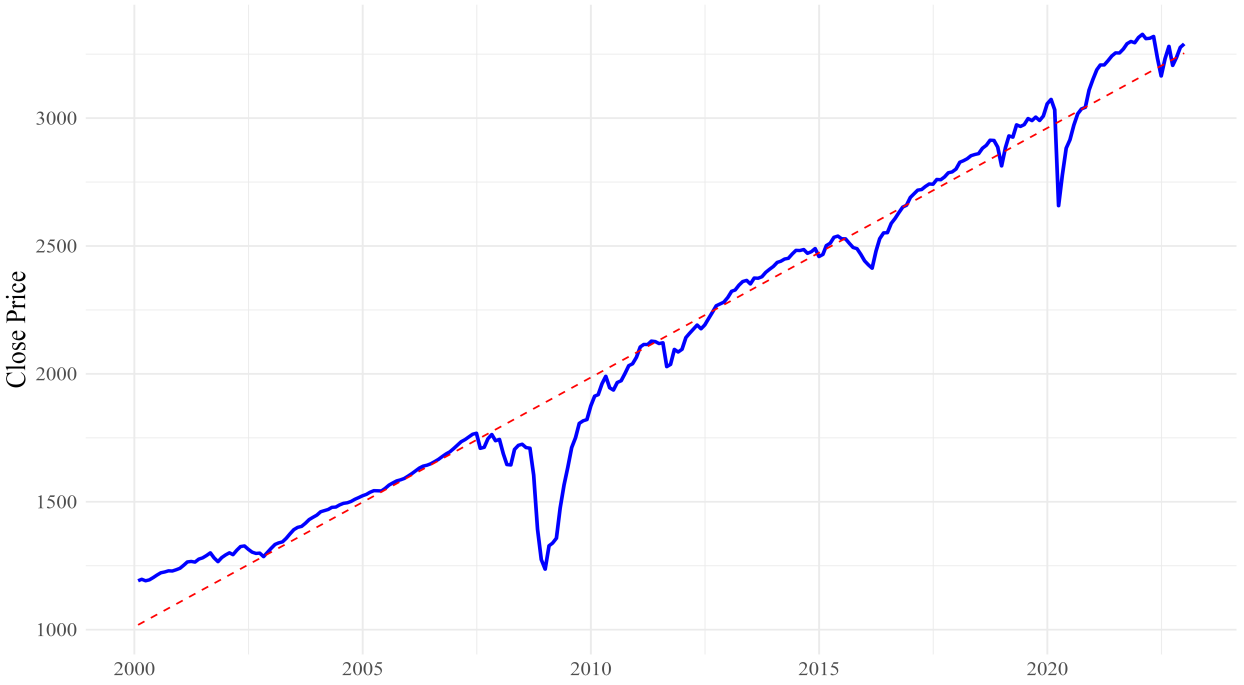


Figure 1: Performance of LSTA Leveraged Loan Index, 2000–2024. The red dotted line shows the best linear fit to the index's performance over this period.

Fact 3: CLO payouts to equity investors are restricted by financial covenants, but these covenants do not reference the market price of CLO loan portfolios. The payouts CLOs make to their equity investors follow strict contractual rules. The interest collected from the loans held by a CLO is placed in an "interest collection account," and all interest payments the CLO owes to its debt investors are then paid out of this account. If the CLO's balance sheet satisfies a list of financial covenants, the remainder of this account can be paid to the equity investors. If there is a covenant violation, the remaining interest in this account is instead used to pay down the CLO's outstanding debt.

CLOs have two main financial covenants—the "overcollateralization test" and the "interest coverage test"—which appear in all indentures in our database. The overcollateralization test examines the ratio of the face value of loans held by a CLO to the face value of outstanding debt. The test is satisfied only if this ratio is sufficiently high, with an average cutoff of 124% in our data. The interest coverage test examines the ratio of the interest payments the CLO receives on the loans it holds to the amount of interest it owes to its debt holders.

This covenant is satisfied only when the ratio is sufficiently high, with an average cutoff of 120%. In all indentures in our database, neither covenant references the market price of CLOs' loan holdings, except for extremely distressed loans. Loans with a credit rating of CCC or worse must often be marked to market, frequently causing a fire-sale of such assets by CLOs (Elkamhi and Nozawa, 2022; Kundu, 2024).

While a violation of either covenant stops the CLO from paying dividends to equity investors, neither forces the CLO to liquidate its assets. Instead, CLOs must use payouts that would have gone to equity to pay down the principal of outstanding debt. As a result, CLOs are not forced to sell assets during severe loan-market downturns, as in 2008 or 2020. This allows them to stay invested and profit from a potential recovery in loan values, as happened after both crises. As documented by Cordell et al. (2021), CLOs created in 2007 had the highest average return on equity, showing that CLOs can even benefit from crises.

3 Model

This section presents our model of the role of CLOs in financial intermediation. We describe the environment in section 3.1. We consider the optimal decisions of a bank who raises funds directly from depositors and equity investors in section 3.2. With then consider the investment decisions of a CLO whose long-maturity debt is held by banks instead of by depositors in section 3.3. Finally, we demonstrate the benefits a financial system with CLOs to one only with banks in section 3.4 but that regulating CLOs is still socially useful in section 3.5.

3.1 Setup

The model has four periods $t = 0, 1, 2, 3$. There is one type of risky asset—loans—and all loans are ex ante identical at $t = 0$. Loans pay off at time 3, and shocks at times 1 and 2 make this payoff risky, as illustrated in Figure 2. There is a binary "good" or "bad" shock

at time 1, followed by a second good or bad shock at time 2, with probability $\Pr(B_t)$ of a bad shock at time t. In what follows, G and B denote a good and a bad shock, respectively, while the subscripts 1 and 2 refer to periods $t = 1$ and $t = 2$. In addition, each loan's quality f is realized i.i.d. at time 1: with probability $\pi(f_{\text{low}})$ a loan is "low quality" $f = f_{\text{low}} < 1$, and otherwise $f = 1$. The payoff δ_f equals 1 if at least one good aggregate shock is realized and equals f otherwise. In addition, at each period there is an elastic supply of "reserves" that are short maturity risk-free assets that payoff at time $t + 1$ when purchased at time t.

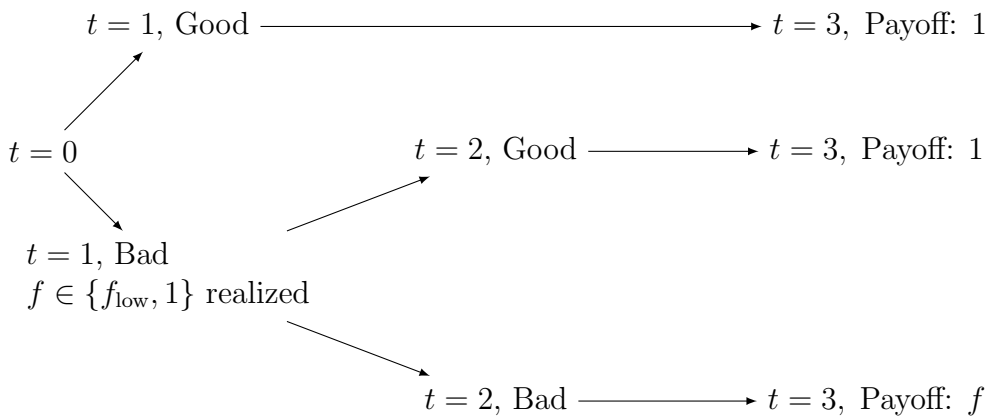


Figure 2: **Loan payoffs and timing.** All loan payoffs occur at time 3 and equal 1 unless bad shocks occur at both times 1 and 2. After two bad shocks, the payoff equals the loan's idiosyncratic quality $f \in \{f_{\text{low}}, 1\}$ realized at time 1.

There are three types of investors: depositors, equity investors, and outside financiers. Depositors are active in all periods, will hold only short-term risk-free assets that are not exposed to potential bank runs, and require a return R_d. Equity investors are active only at time 0, are risk-neutral, and require a return $R_e > R_d$. Any risky asset sold after time 0 is bought by an outside financier, who is risk-neutral with required return $R_a > R_d$, subject to fire-sale costs described below. These investors can invest directly in loans as well as in claims issued by financial intermediaries, who in turn can use the funds they raise to buy loans directly.

Equity Investors Equity investors are active only at time 0 and are risk neutral with discount rate R_e. If they buy an asset at time 0 that pays dividends δ_t^{eq} at time $t > 0$, it

must have a price p_0^{eq} given by

$$p_0^{eq} = E\big[\sum_{t=1}^{3} \frac{\delta_t^{eq}}{(1+R_e)^t}\big]. \tag{1}$$

Depositors and Banks Run Risk. Depositors are infinitely risk-averse investors with discount rate R_d who face an idiosyncratic shock $\lambda \in \{1, 2, 3\}$. In each period $t = 1, 2$, there is a probability $0 < pr_\lambda < 1$ that a depositor learns that $\lambda = t$ is realized. If for depositor i we have $\lambda_i = t$, then it obtains utility only from consumption up to time t. Each depositor i maximizes expected utility over all possible realizations of uncertainty

$$c_{0,i} + \sum_{t=1}^{3} \frac{\{\lambda_i \geq t\} c_{t,i}}{(1+R_d)^t}, \tag{2}$$

where $\{\lambda \geq t\}$ is an indicator function equal to 1 if $\lambda \geq t$ and 0 otherwise.

At time t, all depositors with $\lambda_i = t$ consume their entire wealth, while the remaining depositors have an opportunity to save for the future. Because the consumption choices of a consumer weakly expand with the realization of λ_i, it is rational to invest at time t considering future utility only assuming $\lambda_i = t + 1$.

If a late depositor invests in an asset with price p_t that pays δ_{t+1} and can be liquidated for a value p_{t+1}^{FS}, its first-order condition is

$$p_t = \frac{min_t(\delta_{t+1} + p_{t+1}^{FS})}{1+R_d}, \tag{3}$$

where $min_t(\delta_{t+1})$ denotes the lowest possible realization of δ_t possible given information at time t. This immediately implies that at time 2, since all uncertainty has been realized and assets are now risk-free, an asset paying a dividend δ_f has a price $p_{f,2} = \frac{\delta_f}{(1+R_d)}$ and that reserves always earn an interest rate R_d. In previous periods, depositors care both about the potential value of an asset in a fire sale as well as the cash flows it pays.

Outside Financiers and Fire Sale Discounts. Assets sold to outside financiers after time 0 suffer a fire-sale discount. These fire sales can occur only at times 1 or 2, and at time 2 outside financiers will sell their asset holdings to depositors who have a lower required return $R_d < R_a$. Outside financiers have the choice to either hold assets they buy at time 1 or to sell them in the same period.

Let $s_{f,t}$ be the quantity of loans sold by the outside financier of quality f at time t. Assets sold by an outside financier at time t incur a transaction cost $D(s_{f,t})$ with $D(0) = 0$ and $D'(0) > 0$. If a loan is sold by the outsider financier for price $p_{f,2}$ at time 2, the outside financier receives only

$$p_{f,2}^{\text{FS}} = \left(1 - D(s_{f,2})\right) p_{f,2}.$$

This expression $p_{f,2}^{\text{FS}}$ is the outside financier's willingness to pay for an asset at time 2. Its willingness to pay for an asset at time 1, since the outsider can choose whether to sell the asset or hold it until time 2, is

$$p_{f,1}^{\text{FS}} = max\left\{\left(1 - D(s_{f,2})\right) p_{f,1}, \frac{\text{E}_1[p_{f,2}^{\text{FS}}]}{1+R_a}\right\},$$

where $\text{E}_1[p_{f,2}^{\text{FS}}]$ denote the expectation at time 1 of a loan's value when sold by the outside financier at time 2.

Financial Intermediaries Financial intermediaries are profit-maximizing firms that issue securities to raise funding and can invest in loans or in securities issued by other intermediaries. If an intermediary raises d_0 of debt and e_0 of equity at time 0 and invests I_0, its objective is to maximize time-0 profit

$$d_0 + e_0 - I_0, \tag{4}$$

subject to investing in assets with sufficient future payoffs to compensate investors for the funding d_0, e_0. We first analyze an intermediary that raises all of its funding from depositors

and equity investors, which we refer to as a *bank*. Next, we examine a second intermediary that may also raise funding from the bank; this entity will endogenously take a form matching our stylized facts about CLOs. Appendix A.4 shows that in an economy with both banks and CLOs, there is no incentive for any third type of intermediary to emerge.

3.2 Bank's Problem

Banks raise all of their funding from depositors and equity investors and maximize profits as given by equation 4. Let Q_0^B be the quantity of loans the bank buys at time 0, d_t^{B*} the quantity of deposits it issues at timet $t \geq 0$, and δ_t^B the dividend it pays to equity at time $t > 0$. Because the equity investor is risk-neutral with required return R_e, the equity e_0^B that can be raised at time 0 satisfies

$$e_0^B \;=\; \mathrm{E}\left[\sum_{t=1}^{3} \frac{\delta_t^B}{(1+R_e)^t}\right].$$

The bank chooses a quantity $q_{f,t}^B$ of loans of quality f to hold at times $t \geq 1$ and holdings R_t^B of reserves at each time t.

At each $t > 0$, the bank's depositors have the option to withdraw their funds at the start of the period. A fraction pr_λ of depositors will always withdraw since they realize their liquidity shock $\lambda = t$. The remaining depositors with $\lambda > t$ will also withdraw their funds unless they are sure of future repayment. That is, for any $\gamma_t \in [pr_\lambda, 1]$, the bank must have sufficient funds that all future deposits will be repaid if a fraction γ_t of the bank's depositors withdraw. We only require that the bank is able stay solvent when its own depositors withdraw (so equilibrium asset prices stay fixed), with an extension that examines the possibility of systemic bank runs in appendix A.3.

When a bank experiences a withdraw of deposits $d_{t-1}^{B*}(1 + R_d)\gamma_t$, it liquidates a quantity $q_{f,t}^{B,liq}$ of loans at a price $p_{f,t}^{FS}$ and can also costlessly draw down its reserve balances.

Its objective is to maximize

$$\max_{Q_0^B,\, d_t^{B*},\, q_{f,t}^B, q_{f,t}^{B,liq},\, R_t^B \geq 0} \Big[-p_0 Q_0^B - R_0^B + d_0^{B*} + \mathrm{E}\Big[\sum_{t=1}^{3} \tfrac{\delta_t^B}{(1+R_e)^t} \Big] \Big]. \tag{5}$$

subject to the budget constraints at $t = 1, 2$

$$\begin{aligned} \overbrace{\delta_t^B}^{\text{Dividend payout}} &= \overbrace{\sum_f p_{f,t}\big(q_{f,t-1}^B - q_{f,t}^B\big)}^{\text{Net sale of loans}} + \overbrace{d_t^{B*} - (1+R_d) d_{t-1}^{B*}}^{\text{Net deposit borrowing}} \\ &- \overbrace{\sum_f (p_{f,t} - p_{f,t}^{FS}) q_{f,t}^{B,liq}}^{\text{Loan liquidation losses}} - \overbrace{R_t^B - (1+R_d) R_{t-1}^B}^{\text{Net reserve investment}} \;\geq\; 0, \end{aligned} \tag{6}$$

and at $t = 3$

$$\overbrace{\delta_3^B}^{\text{Dividend payout}} \;=\; \overbrace{\sum_f \delta_f \, q_{f,2}^B}^{\text{Final loan payoff}} \;+\; \overbrace{(1+R_d) R_2^B}^{\text{Final reserve payoff}} \;-\; \overbrace{(1+R_d) d_2^{B*}}^{\text{Final deposit repayment}} \;\geq\; 0, \tag{7}$$

the evolution of loan quality at time 1, $q_{f,0}^B = \pi(f) Q_0^B$, the ability to repay its fraction pr_λ of early depositors who withdraw

$$pr_\lambda d_{t-1}^{B*}(1+R_d) \leq \overbrace{\sum_f p_{f,t}^{FS} q_{f,t}^{B,liq}}^{\text{Loan liquidation proceeds}} + \overbrace{R_{t-1}^B (1+R_d)}^{\text{Reserves available to draw down}}, \tag{8}$$

and a constraint that late depositors are also assured of repayment in all states of the world, even with a possible run on the bank. In the next section, we show that this "no-run constraint" is equivalent to the following condition that ensures the bank could repay all deposits if its entire portfolio is liquidated

$$\overbrace{(1+R_d) d_t^{B*}}^{\text{Payment due to depositors at } t+1} \;\leq\; \overbrace{\sum_f p_{f,t+1}^{FS} \, q_{f,t}^B}^{\text{Fire-sale value of bank assets}} + (1+R_d) R_t^B, \qquad t = 0, 1. \tag{9}$$

3.2.1 Bank's no run constraint

This section shows that a bank which satisfies equation (9) will be able to repay its late depositors in case of a run, ensuring that its deposits are risk-free. The remainder of the paper is self-contained taking equation (9) as given. At times $t = 1, 2$, the bank's depositors have a choice of whether or not to withdraw their deposits. All early depositors will choose to do so, and late depositors will only stay invested if they are sure their deposits will be repaid in the next period. If a bank faces a withdrawal, it must repay depositors by either drawing down its balance of liquid reserves or by selling its other assets to the outside financier.

We work backwards from $t = 2$ to obtain constraints on the bank's portfolio choices that ensure that late depositors will not withdraw. At $t = 2$, the bank enters with an asset portfolio containing loans $q^B_{f,1}$ and reserves $R^B_1(1 + R_d)$, written compactly as the pair $(q^B_{f,1}, R^B_1(1 + R_d))$ and owing deposits $d^{B*}_1(1 + R_d)$. A fraction pr_λ of these deposits are held by depositors who realize $\lambda = 2$ that withdraw their investments. The remaining fraction $1 - pr_\lambda$ of these depositors have a choice of whether to withdraw and invest in reserves or to keep their deposits at the bank. Under the assumption that some fraction $1 \geq \gamma_2 \geq pr_\lambda$ of depositors withdraw, we examine conditions under which the "late" depositors who do not realize $\lambda = 2$ can optimally stay invested.

If a bank liquidates its holding of loans, they must be sold to the outside financier, while reserves can be liquidated with no fire-sale discount. Assets of quality f can be liquidated at price $p^{FS}_{f,2} = \frac{(1-D(s_{f,2}))\delta_f}{1+R_d}$, and a reserve can be liquidated for a value of 1. If a fraction γ_2 of depositors withdraw, the bank must liquidate assets of value

$$\sum_f \frac{(1 - D(s_{f,2}))\delta_f}{1 + R_d} q^{B,liq}_{f,1} + [R^B_1(1 + R_d) - R^B_2] = \gamma_2 d^{B*}_1(1 + R_d). \tag{10}$$

After this, the bank has remaining wealth

$$W^{remaining}_2 = \sum_f \frac{\delta_f}{1 + R_d}[q^B_{f,1} - q^{B,liq}_{f,1}] + R^B_2 \tag{11}$$

and maximizes

$$\overbrace{\left[W_2^{remaining} - \sum_f \frac{\delta_f}{1+R_d} q_{f,2}^B + [d_2^{B*} - (1-\gamma_2)(1+R_d)d_1^{B*}]\right]}^{\text{time 2 dividend}} + \frac{\overbrace{\sum_f \delta_f q_{f,2}^B - (1+R_d)d_2^{B*}}^{\text{time 3 dividend}}}{1+R_e} \tag{12}$$

subject to its dividends being nonnegative as given by equations (6)-(7). This problem has a solution if and only if $W_2^{remaining} \geq (1-\gamma_2)(1+R_d)d_1^{B*}$, which reduces to

$$\sum \frac{(1-D(s_{f,2})\delta_f}{1+R_d} q_{f,1}^{B,liq} + \sum \frac{\delta_f}{1+R_d}[q_{f,1}^B - q_{f,1}^{B,liq}] + (1+R_d)R_1^B \geq (1+R_d)d_1^{B*} \tag{13}$$

which in the most restrictive case of $\gamma_2 = 1$ reduces to

$$\sum \frac{(1-D(s_{f,2})\delta_f}{1+R_d} q_{f,1}^B + (1+R_d)R_1^B \geq (1+R_d)d_1^{B*}. \tag{14}$$

This constraint is equivalent to the bank being able to repay its entire deposit base if it liquidated all assets at time 2.

At time 1, similarly, the bank enters with deposits $d_0^{B*}(1+R_d)$ and has loan holdings $q_{1,f}^B = Q_0^B\pi(f)$ of quality f and reserves $R_0^B(1+R_d)$. If a fraction γ_1 of deposits withdraw, then the bank needs to liquidate assets of value $\sum_f p_{f,1}^{FS} q_{f,1}^{B,liq} + (1+R_d)R_0^B - R_1^B = \gamma_1 d_0^{B*}(1+R_d)$. After this liquidation, the bank has remaining wealth

$$W_1^{remaining} = \sum_f p_{f,1}[Q_0^B\pi(f) - q_{f,1}^{B,liq}] + R_1^B. \tag{15}$$

The bank must choose a portfolio $q_{f,1}^B$ satisfying equation (14) while ensuring its dividend at time 1

$$W_1^{remaining} - \textstyle\sum_f p_{f,1} q_{f,1}^B + [d_1^{B*} - (1-\gamma_1)(1+R_d)d_0^{B*}] \tag{16}$$

is also nonnegative. This is equivalent to

$$\sum_f p_{f,1}[Q_0^B \pi(f) - q_{f,1}^{B,liq} - q_{f,1}^B] + \sum p_{f,1}^{FS} q_{f,1}^{B,liq} + (1+R_d)R_0^B + [d_1^{B*} - (1+R_d)d_0^{B*}] \geq 0. \quad (17)$$

We impose three conditions now which we will hold in equilibrium. First, $p_{f,1} = p_{f,1}^{FS}$, since the outside financier will not buy any assets at time 1 that it immediately resells. Without this condition, our no-run constraint is excessively strict but is never too lax, ensuring that we do not ignore possible equilibria. Second, at time 1, $p_{f,1} \geq \frac{(1-D(s_{f,2}))\delta_f}{1+R_d}$ for the lowest possible realization of δ_f at time 2, so it is not possible to raise one dollar of deposit funding by buying strictly less than one dollar of assets (which would give the bank unbounded profits that cannot occur in equilibrium). Third, d_1^{B*} is chosen so that (14) binds in some state of the world at time 2. Under these conditions, our dividend at time 1 is nonnegative if only if

$$\sum_f p_{f,1}^{FS} Q_0^B \pi(f) + (1+R_d)R_0^B \geq (1+R_d)d_0^{B*}, \quad (18)$$

which again requires the bank to be able to repay all deposits by liquidating its asset holdings, consistent with equation (9).

3.2.2 Simplified Bank's Problem

We now reduce the bank's problem to a simpler one, where the bank's choice of reserves need not be explicitly analyzed. Because the bank earns the same rate on its deposits as it pays on reserves, the bank finds it costless to increase them both by the same amount. Because the bank finds it potentially costly to allow for its loans to be liquidated when depositors withdraw, the bank wants to hold enough reserves to provide the fraction pr_λ of its depositors who redeem at each period. If we define $d_t^B = d_t^{B*} - R_t^B$ and set $R_t^B = pr_\lambda d_t^{B*}$, the bank's problem reduces to one where there are no early-withdrawing depositors. For simplicity, we often refer to d_t^B as a bank's quantity of deposits issued instead of d_t^{B*}. d_t^B is the net increase in liquid assets the bank creates beyond its reserve holdings.

The bank maximizes

$$\max_{Q_0^B,\, d_t^B,\, q_{f,t}^B} \Big[-p_0 Q_0^B + d_0^B + \mathrm{E}\Big[\sum_{t=1}^{3} \tfrac{\delta_t^B}{(1+R_e)^t} \Big] \Big]. \tag{19}$$

subject to the budget constraints

$$\overbrace{\delta_t^B}^{\text{Dividend payout}} = \overbrace{\sum_f p_{f,t}\big(q_{f,t-1}^B - q_{f,t}^B\big)}^{\text{Net sale of assets}} + \overbrace{d_t^B - (1+R_d) d_{t-1}^B}^{\text{Net deposit borrowing}} \;\geq\; 0, \qquad t = 1, 2, \tag{20}$$

$$\overbrace{\delta_3^B}^{\text{Dividend payout}} = \overbrace{\sum_f \delta_f \, q_{f,2}^B}^{\text{Final asset payoff}} - \overbrace{(1+R_d) d_2^B}^{\text{Final deposit repayment}} \;\geq\; 0, \tag{21}$$

the evolution of loan quality at time 1, $q_{f,0}^B = \pi(f) Q_0^B$, and the condition ensuring the bank's liquidation value is enough to repay all deposits

$$\overbrace{(1+R_d) d_t^B}^{\text{Payment due to depositors at } t+1} \;\leq\; \overbrace{\sum_f p_{f,t+1}^{FS} \, q_{f,t}^B}^{\text{Fire-sale value of bank assets}}, \qquad \forall\, t = 0, 1, 2. \tag{22}$$

Bank Portfolio Choices. We first analyze the bank's portfolio choices after aggregate uncertainty is resolved. In period 2, every loan of quality f is known to make a risk-free payoff at time 3 of $\delta_f = 1$ if at least one good aggregate shock occurs and $\delta_f = f$ otherwise. At this point, these loans are short-term risk-free assets that can be held by depositors. Their prices are

$$p_{f,2} \;=\; \tfrac{\delta_f}{1+R_d}. \tag{23}$$

At time 1, such a loan is risk-free in the good state G_1, so the bank can finance the purchase entirely with risk-free deposits. Hence $p_{f,1}(G_1) = \frac{1}{(1+R_d)^2}$. The same price applies to a high-quality loan ($f = 1$) in the bad state. Because these risk-free assets yield $R_d < R_e$, the bank prefers to sell them and pay a current dividend rather than hold them for future dividends. Accordingly, $\delta_3^B = 0$, $\delta_2^B = \sum_f p_{f,2} q_{f,1}^B - (1+R_d) d_1^B$, and $\delta_1^B(G_1) = \frac{Q_0^B}{(1+R_d)^2} - (1+R_d) d_0^B$. We

summarize this in Lemma 1 (proof in Appendix A.1).

Lemma 1. *1. After uncertainty is resolved—either at time 2 or in the good state at time 1—the expected return on every asset equals the risk-free return R_d. High-quality loans ($f = 1$) in the bad state at time 1, being risk-free, also earn R_d.*

2. Because $R_e > R_d$, once uncertainty is resolved the bank pays the largest possible dividend consistent with avoiding default.

Funding a Portfolio Most Efficiently. Next, we consider how a bank chooses its mix of debt and equity financing, holding fixed its investments $(Q_0^B, q_{f,t}^B)$. Because $R_e > R_d$, the bank increases profits by relying on deposit financing whenever possible. The following lemma (proved in Appendix A.1) formalizes this.

Lemma 2. *1. If the bank reaches the bad state B_1 at time 1, it issues the maximum quantity of deposits $d_1^B(B_1)$ that it can repay, given its asset holdings $q_{f,1}^B$.*

2. The bank pays no dividends in the bad state at time 1, since any payout could instead have financed larger deposit issuance at time 0.

Using Lemma 2, the bank's problem reduces to

$$\begin{aligned}\max_{Q_0^B,\, d_0^B,\, q_{f,1}^B \geq 0} \quad & -p_0 Q_0^B + d_0^B + \Pr(G_1)\tfrac{1}{1+R_e}\underbrace{\left[\tfrac{Q_0^B}{(1+R_d)^2} - (1+R_d)d_0^B\right]}_{\text{Dividend in } G_1} \\ & + \Pr(B_1)\Pr(G_2)\tfrac{1}{(1+R_e)^2}\underbrace{\left[\tfrac{\sum_f q_{f,1}^B}{1+R_d} - \tfrac{\sum_f (1-D(s_{f,2}))f\, q_{f,1}^B}{1+R_d}\right]}_{\text{Dividend in } G_2} \\ & + \Pr(B_1)\Pr(B_2)\tfrac{1}{(1+R_e)^2}\underbrace{\left[\tfrac{\sum_f f\, q_{f,1}^B}{1+R_d} - \tfrac{\sum_f (1-D(s_{f,2}))f\, q_{f,1}^B}{1+R_d}\right]}_{\text{Dividend in } B_2}, \end{aligned} \tag{24}$$

subject to the budget constraint in state B_1:

$$\underbrace{\sum_f p_{f,1} q_{f,1}^B}_{\text{Time-1 portfolio choice}} - \underbrace{\frac{\sum_f (1-D(s_{f,2}))f\, q_{f,1}^B}{(1+R_d)^2}}_{\text{Time-1 deposit borrowing}} = \underbrace{Q_0^B \sum_f p_{f,1}(B_1)\pi(f) - (1+R_d)d_0^B}_{\text{Net worth at time 1 in } B_1}. \tag{25}$$

This reduction highlights two core elements of intermediation in the model. First, the bank seeks to finance its loan purchases Q_0^B with "cheap" deposits (R_d) rather than "expensive" equity (R_e). Second, only in bad states—when loan payoffs remain risky—must the bank hold equity as a buffer, because deposits must be risk-free.

The bank can sell low-quality loans after a bad shock to reduce risk, but such sales incur fire-sale discounts that lower the value it can pledge to depositors. If a low-quality loan pays f in the worst state, a bank that holds that asset the bank can pledge at most $(1 - D(s_{f,2}))f$ of that payoff to depositors. The possibility of a run makes the bank averse to holding assets at risk of fire sales.

The Bank's Willingness to Pay for Assets. When the bank buys a loan at time 0, it may either sell after a bad shock at time 1 or hold to maturity. In (25), the market value of Q_0 loans in the bad state is

$$Q_0 \sum_f p_{f,1}(B_1)\pi(f) \;=\; Q_0 \Big[\pi(f_l) p_{f_l,1} + \tfrac{1-\pi(f_l)}{(1+R_d)^2}\Big],$$

since high-quality loans trade at $\frac{1}{(1+R_d)^2}$ and low-quality loans at $p_{f_l,1}$ (from (3.1)). If these proceeds are reinvested solely in high-quality risk-free loans at time 1, the risk-free payoff to depositors at time 3 is

$$\delta_d^{\text{FS}} = (1+R_d)^2 \Big[\underbrace{\tfrac{1-\pi(f_l)}{(1+R_d)^2}}_{\text{Hold high-quality loans}} + \underbrace{\pi(f_l)\, \tfrac{(1-D(s_{f,2}))\left(\Pr(G_2)+f\ \Pr(B_2)\right)}{(1+R_a)(1+R_d)}}_{\text{Sell low-quality loans}} \Big]. \tag{26}$$

Because the bank then holds no risky assets, it has no future cash flows beyond those promised to depositors. Its time-0 willingness to pay for a loan it will sell in a fire sale is

$$p_0^{B,\mathrm{FS}} = \underbrace{\frac{\delta_d^{\mathrm{FS}}}{(1+R_d)^3}}_{\text{Risk-free deposits}} + \underbrace{\frac{\Pr(G_1)}{1+R_e}\left[\frac{1-\delta_d^{\mathrm{FS}}}{(1+R_d)^2}\right]}_{\text{Dividend in } G_1}. \tag{27}$$

If instead the bank holds loans to maturity, a fraction $\pi(f)$ pay f at time 3. The amount that can be pledged to depositors—accounting for fire-sale discounts—is

$$\delta_d^{B,\mathrm{HTM}} = \sum_f (1 - D(s_{f,2}))\, f\, \pi(f).$$

All remaining cash flows must be paid as dividends, discounted at $R_e > R_d$. Hence the bank's willingness to pay for a hold-to-maturity loan is

$$\begin{aligned} p_0^{B,\mathrm{HTM}} = {} & \tfrac{\delta_d^{B,\mathrm{HTM}}}{(1+R_d)^3} + \tfrac{\Pr(G_1)}{1+R_e}\left[\tfrac{1-\delta_d^{B,\mathrm{HTM}}}{(1+R_d)^2}\right] + \tfrac{\Pr(B_1)\Pr(G_2)}{(1+R_e)^2}\left[\tfrac{1-\delta_d^{B,\mathrm{HTM}}}{1+R_d}\right] \\ & + \tfrac{\Pr(B_1)\Pr(B_2)}{(1+R_e)^2}\left[\tfrac{\sum_f f\,\pi(f)-\delta_d^{B,\mathrm{HTM}}}{1+R_d}\right]. \end{aligned} \tag{28}$$

Proposition 1. *1. A bank's time-0 willingness to pay for a loan that will be sold at time 1 is given by* (27)*; for a loan held to maturity, by* (28)*.*

2. In an economy where banks hold all loans, the bank is indifferent between these strategies, which pins down the equilibrium fire-sale discount $D(s_{f_l,2})$ for low-quality loans.

3. If the bank could instead buy a perfectly risk-free three-period loan with $\pi(f_l) = 0$, its price would be $\frac{1}{(1+R_d)^3}$. Thus the bank invests in long-maturity risk-free debt at the same yield as its deposit cost of capital R_d.

3.3 Collateralized Loan Obligations

We now examine the investment decisions of an intermediary financed with a mix of equity and risk-free long-term debt, which we call a collateralized loan obligation (CLO). Because the bank is willing to invest in long-term risk-free debt at the return R_d, the CLO can borrow at the same rate R_d, issuing d_0^C of risk-free debt at time 0. The CLO's equity investor is risk-neutral with required return R_e, so the CLO can raise equity of

$$e_0^C \;=\; \mathrm{E}\left[\sum_{t=1}^{3} \tfrac{\delta_t^C}{(1+R_e)^t}\right],$$

where δ_t^C is the dividend paid at time t. The CLO buys Q_0^C loans at time 0 and $q_{f,t}^C$ loans of quality f at times $t > 0$. Its objective is

$$\max_{Q_0^C,\, d_0^C,\, q_{f,t}^C} \left\{ -p_0 Q_0^C + d_0^C + \mathrm{E}\left[\sum_{t=1}^{3} \tfrac{\delta_t^C}{(1+R_e)^t}\right] \right\}. \tag{29}$$

subject to the quality evolution $Q_0^C \pi(f) = q_{f,0}^C$ of loans at time 1 and the budget constraints

$$\overbrace{\delta_t^C}^{\text{Dividend payout}} \;=\; \overbrace{\sum_f p_{f,t}\big(q_{f,t-1}^C - q_{f,t}^C\big)}^{\text{Net asset sales}} \;\geq\; 0, \qquad t = 1, 2, \tag{30}$$

$$\overbrace{\delta_3^C}^{\text{Dividend payout}} \;=\; \overbrace{\sum_f \delta_{f,3}\, q_{f,2}^C}^{\text{Final asset payoff}} \;-\; \overbrace{(1+R_d)^3 d_0^C}^{\text{Debt repayment}} \;\geq\; 0, \qquad t = 3. \tag{31}$$

The crucial difference between the CLO and the bank is the absence of an added no-run constraint for the CLO. Because its debt is long-term, there is no possible for its lenders to run on the CLO. The safety of CLO debt there depends only on the CLO generating sufficient cash flows to make its promised payments. Like the bank, the CLO prefers low-cost debt to high-cost equity. Unlike the bank, it need not remain mark-to-market solvent in a fire sale. Consequently, we will show that a CLO issues strictly more long-term risk-free debt than the short-term deposits a bank can issue.

CLO Portfolio Choices As with the bank, the required return R_d on the CLO's risk-free debt is strictly below the required return R_e on its equity. Consequently, for any given asset choice $(Q_0^C,\, q_{f,t}^C)$, the CLO issues the maximum feasible amount of risk-free debt d_0^C. Because all assets earn the risk-free rate $R_d < R_e$ once aggregate uncertainty is resolved, the CLO pays the largest possible dividend after uncertainty is resolved. On this basis we establish the following lemma (proved in Appendix A.1), which is the analogue to Lemmas 1–2 for banks.

Lemma 3. *1. After aggregate uncertainty is resolved—either at time 2 or in the good state at time 1—the CLO pays the maximum dividend consistent with repaying its debt.*

2. Given its portfolio choice $q_{f,1}^C$ in the bad state at time 1, the CLO issues the largest possible quantity of risk-free debt d_0^C. The promised repayment at time 3 therefore equals the lowest possible realized payoff $\sum_f q_{f,1}^C f$ of that portfolio.

3. The CLO pays no dividend in the bad state at time 1, because retaining that cash flow would have allowed it to issue additional risk-free debt d_0^C.

Unlike the bank, the CLO can borrow against the *entire* cash flow $\sum_f q_{f,1}^C f$ that its portfolio pays in the worst state of the world. The bank, by contrast, can borrow against only the smaller amount $\sum_f (1 - D(s_{f,2}))\, q_{f,1}^C f$ because it must be able to survive a potential run. As shown in Appendix A.1, the CLO's problem therefore reduces to

$$\max_{Q_0^C,\, q_{f,1}^C \geq 0} \underbrace{\frac{\sum_f q_{f,1}^C f}{(1+R_d)^3}}_{\text{Risk-free borrowing}} - p_0 Q_0^C + \frac{\Pr(G_1)}{1+R_e} \underbrace{\left[\frac{Q_0^C - \sum_f q_{f,1}^C f}{(1+R_d)^2}\right]}_{\text{Dividend in } G_1} + \frac{\Pr(G_2)\Pr(B_1)}{(1+R_e)^2} \underbrace{\left[\frac{\sum_f (1-f)\, q_{f,1}^C}{1+R_d}\right]}_{\text{Dividend in } G_2}, \tag{32}$$

subject to the budget constraint in state B_1:

$$\sum_f p_{f,1}(B_1)\, q^C_{f,1} \;=\; Q^C_0 \sum_f \pi(f)\, p_{f,1}(B_1). \tag{33}$$

Equation (32) highlights the CLO's advantage over the bank. Because the CLO can devote the full payoff $\frac{\sum_f q^C_{f,1} f}{(1+R_d)^3}$ to risk-free debt service, it is not forced to retain any portion as a lower-valued equity dividend. The CLO's long-term debt is immune to runs, so fluctuations in asset prices do not constrain its ability to issue risk-free claims. Apart from this distinction, the CLO faces the same costs of debt and equity as the bank. Hence, holding risky loans on the CLO's balance sheet is strictly superior to having those loans held directly by banks.

The CLO's Willingness to Pay for Assets. We now examine the CLO's willingness to pay for loans that it either holds to maturity or sells at time 1. If the CLO holds a portfolio of loans to maturity, each unit of loans yields a cash flow of 1 in every state except the bad state at time 2, in which it pays $\sum_f f\pi(f)$. The CLO can therefore issue risk-free debt paying $\sum_f f\pi(f)$ backed by this asset. The remaining loan payoffs must be funded by equity; in any good state there is a residual cash flow $1 - \sum_f f\pi(f)$ that can be paid as a dividend. The first-order condition for loans held to maturity is

$$p_0^{C,\mathrm{HTM}} = \tfrac{\sum_f f\pi(f)}{(1+R_d)^3} + \tfrac{\Pr(G_1)}{1+R_e}\Big[\tfrac{1-\sum_f f\pi(f)}{(1+R_d)^2}\Big] + \tfrac{\Pr(G_2)\Pr(B_1)}{(1+R_e)^2}\Big[\tfrac{1-\sum_f f\pi(f)}{1+R_d}\Big]. \tag{34}$$

If instead the CLO buys a loan at time 0 that it sells at time 1 in the bad state, it receives the same resale price as the bank. Reinvesting the proceeds in risk-free assets produces the payoff

$$\delta_d^{\mathrm{FS}} = (1+R_d)^2\Big[\underbrace{\tfrac{1-\pi(f_l)}{(1+R_d)^2}}_{\text{High-quality loans}} + \underbrace{\pi(f_l)\,\tfrac{(1-D(s_{f,2}))\left(\Pr(G_2)+f\Pr(B_2)\right)}{(1+R_a)(1+R_d)}}_{\text{Sale of low-quality loans}}\Big]. \tag{35}$$

The price the CLO is willing to pay at time 0 for a loan it will sell at time 1 is therefore

$$p_0^{C,\mathrm{FS}} = \frac{\delta_d^{\mathrm{FS}}}{(1+R_d)^3} + \frac{\Pr(G_1)}{1+R_e}\left[\frac{1-\delta_d^{\mathrm{FS}}}{(1+R_d)^2}\right], \tag{36}$$

identical to the bank's $p_0^{B,\mathrm{FS}}$ in equation 27.

The CLO's willingness to pay is thus weakly higher than the bank's. For hold-to-maturity loans, equation 34 coincides with the bank's expression in equation 28 when $D(s_{f,2}) = 0$; with any positive fire-sale discount, the CLO values holding a loan strictly more than a bank does. This yields the following proposition.

Proposition 2. *1. For a loan held to maturity, the CLO's willingness to pay is given by equation 34. If $D(s_{f_l,2}) > 0$, this exceeds the bank's willingness to pay.*

2. For a loan sold in the bad state at time 1, the CLO's willingness to pay is equation 36, identical to the bank's $p_0^{B,\mathrm{FS}}$.

3. In equilibrium the CLO is indifferent between the two strategies; setting equations 34 and 36 equal pins down the equilibrium fire-sale discount $D(s_{f,2})$.

4. One equilibrium has the CLO holding all risky loans while the bank holds only the CLO's risk-free debt. Any other equilibrium delivers identical asset prices and payoffs to depositors and shareholders.

Figure 3 illustrates the financial system's organization. Without CLOs, banks hold risky, long-maturity loans financed by debt and equity. When CLOs expand to steady-state size, they absorb all risk: CLO equity—not bank equity—bears it. The bank conducts pure maturity transformation with long-maturity risk-free assets financed entirely by short-term deposits, avoiding fire-sale discounts. The CLO performs *safety transformation*; the bank performs *maturity transformation*, insulating the banking sector from loan fire sales. That said, banks are not superfluous, since depositors that held AAA CLO debt would have to fire-sell the debt if they received an early liquidity shock $\lambda = t$ at time t. Here, the bank is

able to hold a mix of AAA debt and reserves to diverisfy across depositors' liquidity shocks. The bank draws down its reserves when depositors withdraw, ensuring that all long-term AAA debt can be held to maturity.

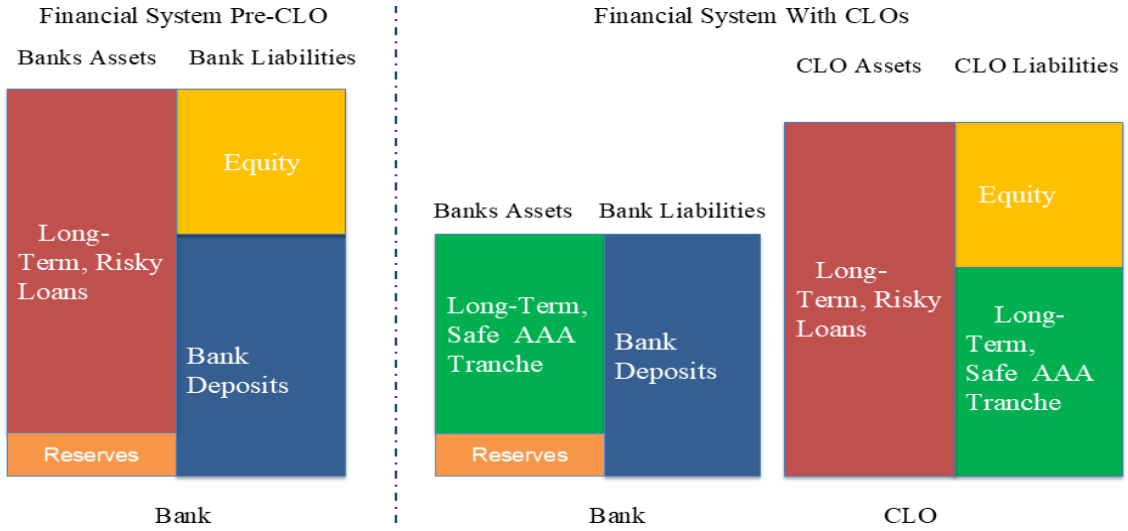


Figure 3: Organization of the financial system with and without CLOs. Without CLOs, banks transform risky, long-maturity, illiquid loans into safe, short-term deposits. With CLOs, risky loans are transformed into long-maturity AAA debt, allowing banks to engage solely in risk-free maturity transformation.

3.3.1 Empirical Realism of the Model's CLOs

This section documents how our model provides an empirically *realistic* description of CLOs, based on the stylized facts in Section 2, and discusses extensions that add to the model's realism. First, the model aligns with Fact 1: CLOs raise most of their funding through long-maturity AAA debt that is held by banks. While matching the precise quantity of AAA issuance requires calibration (presented in Section 4), Figure 3 shows that CLOs in our model are indeed funded with long-maturity debt held by banks. The model is also consistent with Fact 2: CLOs are the largest investors in the leveraged-loan market. In the benchmark equilibrium all loans are held endogenously by CLOs, whose balance-sheet structure is best suited to this market.

The model also matches finer features of actual CLO portfolios. First, the CLO pays

dividends only when a good aggregate shock occurs. This accords with Fact 3: real CLOs face covenants that suspend dividends when balance sheets deteriorate. Our CLO can be viewed as having "violated a covenant" in bad states when it cannot pay dividends; similarly, an actual CLO in covenant violation diverts cash flows to debt repayment. Like real over-collateralization and interest-coverage tests, our restriction in equation (31) that ensures CLO debt is repaid does not reference market prices.

Indeed, in state B_2—after fire-sales with $s_{f,2} > 0$—the liquidation value of a CLO's assets is *less* than the market value of its outstanding debt. The resale value equals

$$q^C_{1,1}(B_1)\tfrac{1}{1+R_d} \;+\; q^C_{f_l,1}(B_1)\tfrac{\left(1-D(s_{f,2})\right)f_l}{1+R_d},$$

whereas the value of the risk-free debt to be *repaid* is the strictly larger

$$q^C_{1,1}(B_1)\tfrac{1}{1+R_d} \;+\; q^C_{f_l,1}(B_1)\tfrac{f_l}{1+R_d}.$$

It is precisely because the CLO may be mark-to-market insolvent in the worst state that it is a more efficient holder of fire-sold assets than a bank financed by runnable deposits. As long as those assets generate the promised cash flows by time 3, the CLO can hold them safely at time 2.

The model's bad-state behavior is consistent with empirical evidence on distressed CLOs (Elkamhi and Nozawa, 2022; Kundu, 2023). When close to violating a covenant, CLOs typically sell their lowest-quality loans and use the proceeds to retire debt, restoring covenant compliance in order to pay dividends. In our model, in the time-1 bad state the CLO sells $s_{f_l,2}$ low-quality loans at

$$p_{f_l,1} = \frac{\left(1-D(s_{f_l,2})\right)\left(\Pr(G_2)+f_l\Pr(B_2)\right)}{(1+R_a)(1+R_d)}.$$

The proceeds $p_{f_l,1}s_{f_l,2}$ are invested in risk-free assets, effectively "buying back" the CLO's

own floating-rate AAA bonds and paying down debt—exactly the practice documented by Elkamhi and Nozawa (2022).

Our model thus unifies several stylized facts about CLO design. Long-term debt financing shields CLOs from runs when asset values temporarily fall, whereas a short-term-funded institution might fail to roll over its debt. CLOs are therefore well suited to holding illiquid assets subject to fire-sale pressure. They can rebalance such portfolios over time because fire-sale discounts do not threaten a run. Finally, since CLOs can withstand mark-to-market losses, their covenants need not reference market prices. This combination—long-term debt, actively rebalanced illiquid portfolios, and covenants that ignore market prices—makes the CLO structure especially valuable for financial intermediation.

Extensions. One empirically unrealistic feature of our economy, relaxed in appendix A.3, is that banks and CLOs borrow at exactly the same risk-free interest rate R_d. This is due to the fact that banks in our economy can finance their holdings of risk-free assets entirely by issuing deposits, making pure maturity transformation effectively costless for banks. In appendix A.3, we modify our model so that banks must be able to repay depositors not only in a run on an individual bank but in a systemic run on the entire banking system. Here, CLOs still emerge in equilibrium, even though their AAA debt may experience a fire sale during a systemic bank run. The yield on CLOs' AAA debt is strictly above the deposit rate to compensate for this risk. CLOs still insulate banks from fire-sales so long as low-quality loans experience worse fire-sale discounts than high-quality ones. Our conclusions about the structure of CLOs are robust, even though this extended model is less tractable.

Our model also abstracts from the role of non-bank investors in the debt issued by CLOs, where insurance companies (DeMarco et al., 2020) have the largest holdings. Insurers face solvency regulations similar to banks, but their long-maturity liabilities mean that they are not exposed to the risk of a bank run. Unlike for CLOs, risk regulations for insurance

companies compare their existing asset portfolios to their outstanding liabilities without accounting for the possibility of future portfolio rebalancing. As we show in appendix A.5, an insurer with such a constraint on its risk taking would prefer to hold the risk-free debt of a CLO than to hold risky loans directly.

Finally, we show in appendix A.6 that our main conclusions are robust to various specifications of our bank's no run constraint. If banks only had to worry about a fraction of their depositors withdrawing in a run, or if bank regulators provided some partial deposit insurance while imposing regulations that deposits can eventually be repaid, CLOs would still emerge in equilibrium. Only if regulators provided complete deposit insurance, removing the fear of a run, would CLOs no longer be essential. However, the profitability of introducing CLOs to a traditional banking system decreases with the amount of deposit insurance. If we think that U.S. bank regulators became less generous in providing liquidity support after the 2008 crisis (Falasconi, 2025), our model suggests that this would be a natural time to see growth in the CLO sector. Through the lens of our model, this growth in CLOs is not merely regulatory arbitrage but also a useful private-sector innovation to avoid liquidity crises.

3.4 Quantifying the Benefits of CLOs

We now use our model to quantify the benefits of a CLO-based financial *system* over a traditional one in which banks lend directly to firms.

First, we compute the leverage a CLO can attain by avoiding the bank's mark-to-market solvency constraint. If the CLO buys loans and holds them to maturity, it can issue risk-free debt that pays

$$\sum_f f\,\pi(f)$$

at time 3. By contrast, a bank holding the same portfolio can promise at most

$$\sum_f \big(1 - D(s_{f,2})\big)\, f\,\pi(f)$$

to its depositors. Hence the CLO can pledge the additional risk-free cash flow

$$\Delta_d = \sum_f D(s_{f,2})\, f\, \pi(f),$$

which the bank would instead have to divert to equity dividends. Because of this greater borrowing capacity, the CLO is willing to pay more for such loans than a bank. The extra willingness to pay equals the value of funding Δ_d with debt rather than equity, yielding the following proposition (proved by subtracting equations 28 and 34):

Proposition 3. *Relative to a traditional system in which banks lend directly to firms, the time-0 price p_0 of loans in a system with CLOs is strictly higher. The price difference is*

$$\big(\Delta^{RR}\big) \sum_f D\big(s^B_{f,2}\big)\, f\, \pi(f),$$

where

$$\Delta^{RR} = \tfrac{1}{(1+R_d)^3} - \tfrac{\Pr(G_1)}{(1+R_e)(1+R_d)^2} - \tfrac{\Pr(B_1)\Pr(G_2)}{(1+R_e)^2(1+R_d)} - \tfrac{\Pr(B_2)\Pr(B_1)}{(1+R_e)^2(1+R_d)}, \tag{37}$$

and $s^B_{f,2}$ is the equilibrium quantity of loan f sold to outside financiers in the bank-only economy.

Financial-stability Implications We next show that a system with CLOs is more stable, featuring fewer fire sales than a banking-only system. In either economy, some low-quality loans f_l are liquidated in the time-1 bad state. From equations 27, 36, and the definition of δ_d^{FS} in equation 35, loan prices must satisfy

$$\begin{aligned} p_0 = {} & \left[\tfrac{1}{1+R_d} - \tfrac{\Pr(G_1)}{1+R_e}\right] \tfrac{1-\pi(f_l)}{(1+R_d)^2} + \tfrac{\Pr(G_1)}{(1+R_e)(1+R_d)^2} \\ & + \pi(f_l)\big(1 - D(s_{f_l,2})\big) \left[\tfrac{1}{1+R_d} - \tfrac{\Pr(G_1)}{1+R_e}\right] \tfrac{\Pr(G_2)+f_l \Pr(B_2)}{(1+R_a)(1+R_d)}. \end{aligned} \tag{38}$$

Let $(p_0^{\text{bank}}, p_0^{\text{CLO}})$ denote the equilibrium prices and $(s_{f_l,2}^{\text{bank}}, s_{f_l,2}^{\text{CLO}})$ the associated fire-sale quantities in the two systems. Because the only term differing across economies in (38) is $s_{f_l,2}$, we have

$$p_0^{\text{CLO}} - p_0^{\text{bank}} = \pi(f_l)\big[D\big(s_{f_l,2}^{\text{bank}}\big) - D\big(s_{f_l,2}^{\text{CLO}}\big)\big]\Big[\tfrac{1}{1+R_d} - \tfrac{\Pr(G_1)}{1+R_e}\Big]\tfrac{\Pr(G_2)+f_l\Pr(B_2)}{(1+R_a)(1+R_d)}. \tag{39}$$

Since Proposition 3 implies $p_0^{\text{CLO}} > p_0^{\text{bank}}$, equation (39) requires $D(s_{f_l,2})$ to be smaller with CLOs. Because $D(\cdot)$ is derived from a downward-sloping demand curve, a smaller discount means a *smaller* fire-sale quantity. We summarize in the following proposition.

Proposition 4. *Equation* (39) *gives the loan-price difference between a CLO system and a banking-only system. Because prices are higher with CLOs, the associated fire-sale discount and quantity are lower, making the financial system more stable.*

3.5 Optimal Regulatory Interventions

This section shows that CLOs engage in inefficiently many fire sales and that restricting such sales maximizes welfare. Although introducing CLOs improves the financial system relative to one with only banks, regulatory intervention may still be warranted. A regulator can act either by capping the quantity of loans that may be fire-sold or by limiting CLOs' ex-ante leverage. The optimal policy induces CLOs to hold a larger fraction of loans to maturity and to sell fewer low-quality loans at time 1. The motivation for regulation is purely "macroprudential" in the sense that private sector agents are able to prevent CLO default but do not internalize the impact of their choices on equilibrium prices.

Because depositors, equity investors, and outside financiers all have linear preferences, the time-0 loan price p_0 is a sufficient statistic for utilitarian welfare. The optimal intervention therefore maximizes p_0. We study how p_0 varies with the amount $s_{f_l,2}$ of low-quality loans fire-sold at time 1 and then resold by the outside financier w at time 2. We compare the privately and socially optimal choices. Note that $\frac{s_{f_l,2}}{\pi(f_l)}$ is the fraction of all low-quality loans

that the CLO sells, since there is unit mass of loans, of which $\pi(f_l)$ turn out low quality.

Private choice If the CLO commits ex ante to sell the fraction $\frac{s_{f_l,2}}{\pi(f_l)}$ and hold the remainder to maturity, its willingness to pay is

$$p_0 \;=\; \Big(1 - \tfrac{s_{f_l,2}}{\pi(f_l)}\Big) p_0^{C,\mathrm{HTM}} \;+\; \tfrac{s_{f_l,2}}{\pi(f_l)}\, p_0^{C,\mathrm{FS}}\big(s_{f_l,2}\big), \tag{40}$$

where $p_0^{C,\mathrm{HTM}}$ is given in equation 34 and $p_0^{C,\mathrm{FS}}(s_{f_l,2})$ in equation 36. Treating $p_0^{C,\mathrm{FS}}(\cdot)$ as fixed, a profit-maximizing CLO chooses $s_{f_l,2}$ such that

$$p_0^{C,\mathrm{HTM}} = p_0^{C,\mathrm{FS}}\big(s_{f_l,2}\big),$$

which pins down the unregulated fire-sale quantity.

Social choice. A utilitarian planner internalizes the impact of $s_{f_l,2}$ on prices and chooses $s_{f_l,2}^{\mathrm{social}}$ to maximize expression 40, yielding the first-order condition

$$p_0^{C,\mathrm{HTM}} \;=\; \Big[p_0^{C,\mathrm{FS}}\big(s_{f_l,2}^{\mathrm{social}}\big) + s_{f_l,2}^{\mathrm{social}}\, \tfrac{\mathrm{d}p_0^{C,\mathrm{FS}}}{\mathrm{d}s_{f_l,2}}\Big(s_{f_l,2}^{\mathrm{social}}\Big)\Big]. \tag{41}$$

Differentiating equation 41 yields

$$\tfrac{\mathrm{d}p_0^{C,\mathrm{FS}}}{\mathrm{d}s_{f_l,2}} = -\Big[\tfrac{1}{1+R_d} - \tfrac{\Pr(G_1)}{1+R_e}\Big] \tfrac{\pi(f_l)\, D'\big(s_{f_l,2}\big)\,\big(\Pr(G_2)+f_l\Pr(B_2)\big)}{(1+R_a)(1+R_d)} \;<\; 0,$$

implying $p_0^{C,\mathrm{FS}}\big(s_{f_l,2}^{\mathrm{social}}\big) > p_0^{C,\mathrm{HTM}}$. Private agents must be *constrained*. They would otherwise oversell low-quality loans, yet the social optimum still has $s_{f_l,2}^{\mathrm{social}} > 0$. Macroprudential regulation restricts, but does not ban, fire sales of loans.

Equivalence with buy-and-hold. In the unregulated economy the loan price p_0 is exactly the same as if $s_{f_l,2} = 0$ and CLOs were pure buy-and-hold securitization. Private gains from trading are fully offset by the negative externality of fire sales.

Proposition 5. *1. In the unregulated economy, CLOs sell* more *low-quality loans than*

is socially optimal.

2. *The socially optimal fire-sale quantity $s_{f_l,2}^{social}$ solves equation 41; it is positive but strictly below the unregulated level.*

3. *Aggregate welfare in the unregulated CLO economy equals that in a buy-and-hold securitization regime where $s_{f_l,2} = 0$. Welfare is strictly higher with optimal regulation.*

4 Numerical Example

In this section, we present a simple calibration of our model to quantitatively compare the different financial systems we qualitatively compared above. In section 4.1, we calibrate the model to metrics such as CLO debt and equity returns, the probability of a bad state (which we see as a financial crisis), empirical measures of fire-sale discounts, CLO capital structure, and the returns on a leveraged loan portfolio. Section 4.2 compares the welfare and financial stability of a CLO-based financial structure to a "buy-and-hold securitization" system, a bank-only financial system, and the constrained-efficient allocation. In doing so, we show that CLOs are most socially useful when loan illiquidity is neither too high or too low.

4.1 Calibration

The model parameters and the model fit to the data targets are presented in Tables 1 and 2. Further details on the calculation of model moments are provided in Appendix B.

First, we externally calibrate some parameters directly observed in data. We set the return on the CLO equity tranche, R_e, and the AAA debt tranche, R_d, to 9.88% and 2.33%, respectively, following Cordell et al. (2021). We impose that the fire sales discount follows the functional form

$$D(s_{f,2}) = 1 - \exp(-\kappa s_{f,2}).$$

This exponential functional form implies that $\frac{1}{\exp(-\kappa s_{f,2})} \frac{d(1-D(s_{f,2}))}{ds_{f,2}}$ is constant, so that selling

a given fraction of the outstanding stock of an asset decreases its price by a fixed fraction of its current value. We use this functional form to match the estimates of Elkamhi and Nozawa (2022). They find that selling 1% of the total outstanding stock of CCC-rated loans by CLOs decreases their price by 2.34%, and 40% of such loans are owned by CLOs. A sale of 1% of CLO holdings of a loan should depress its price by $.4 * 2.34\% = .936\%$. We calibrate the probability $Pr(B)$ of a bad shock to 5.06%, matching the probability of a severe price decline in the Morningstar LSTA Leveraged Loan Index as detailed in appendix B.

We calibrate our remaining three parameters $(R_a, f_l, \pi(f_l))$ to target four empirical moments. First, we target the leverage of CLOs to be 63% AAA debt based on the mean in our Semeris dataset of CLO indentures. Next, we target three moments based on the returns on the LSTA Leverage Loan index. The average return on loans is targeted at 5.1%. The return when entering the bad state is targeted at -20%, and the return when exiting a crisis is targeted at 36%, so that loans recover almost entirely after a crisis. The details of how these moments were calculated is in appendix B.

Table 1: Model Parameters

Targets	**Definition**	**Value**	**Source**
Return on CLO equity tranche	R_e	0.0988	Cordell et al. (2021)
Return on CLO AAA debt tranche	R_d	0.0233	Cordell et al. (2021)
Probability of crisis	$\Pr(B)$	0.083	LSTA US Leveraged Loan (2000-2024)
CLO fire sale discount	κ	0.936	Elkamhi and Nozawa (2022)
Outside Discount rate	R_a	0.0437	Calibrated to Fit Table 2
Pr(Bad Loan in Bad State)	$\pi(f_l)$	0.6419	Calibrated to Fit Table 2
Worst Loan Payoff	f_l	0.3004	Calibrated to Fit Table 2

Baseline parameterization of the model.

We present our model's parameters in table 1 and its fit relative to targeted moments in table 2. Despite its simplicity, the model aligns well with the data, particularly in achieving a CLO leverage level of 60%, even with a significant fire-sale discount that limits the CLO's ability to maintain risk-free debt. The model nearly replicates the price change of the LSTA

Leveraged Loans Index in and out of crises, achieving values of 0.80 and 1.31 respectively, and captures the unconditional average return on the loan index at 3.5% is only somewhat below the observed 5.1%.

Table 2: Model Fit

Targets	**Data**	**Model**	**Source**
CLO Leverage	0.63	0.60	Semeris
Annual Expected Return on Leveraged Loan	1.051	1.035	LSTA US Leveraged Loan (2000-2024)
Price Change on Leveraged Loan into crisis	0.79	0.80	LSTA US Leveraged Loan (2000-2024)
Price Change on Leveraged Loan out of crisis	1.36	1.31	LSTA US Leveraged Loan (2000-2024)

Data targets used to calibrate the model as well as the corresponding model values. Returns are reported in annualized levels.

4.2 Comparing Financial Systems

In this section we compare equilibria across four different possible financial systems. First, we examine our benchmark with CLOs that was calibrated to the data. Second, we examine a "buy and hold securitization" system where all loans are held by CLOs but where CLOs do not rebalance their porfolios over time. Third, we examine a "traditional banking" system, where banks that issue deposits directly hold all loans. Finally, we examine the social optimum: a CLO system with a socially optimal constraint on the quantity of fire sales.

Table 3 compares the quantity d_0 of risk-free debt, the price p_0 of loans, and the fraction $\frac{s_{f_l,2}}{\pi(f_l)}$ of bad loans sold across the three economies. Consistent with our theoretical analysis, the loan price p_0 (and hence welfare) is lowest in the traditional banking economy, equal in the unregulated CLO system and buy-and-hold securitization system, and strictly greatest in the optimally regulated CLO system. The differences are somewhat modest, with the banking system 60 basis points below the CLO system and the social optimum 20 basis

points above. As a rough calculation, these differences relative to the $1.3 trillion market for leverage loans yield a $7.8 billion dollar social gain by adding CLOs or buy-and-hold securitization to a traditional banking system and an additional $2.6 billion from regulating CLOs optimally.

The differences in the quantities of safe debt issuance vary somewhat more, with buy-and-hold securitization only resulting in a quantity $d_0 = .514$ of risk-free debt and the CLO creating $d_0 = .596$. The banking system and the social optimum are somewhere in between at $d_0 = .564$ and $d_0 = .570$ respectively. The largest differences, however, are in the quantity of loans sold across the different economics. Consistent with our theoretical analysis, the traditional banking system, has 54% of bad loans sold relative to only 43% in the CLO system. This illustrates the financial stability benefits of introducing CLOs. However, the socially optimal quantity is only 20%, so CLOs sell more than double the socially optimal quantity of low-quality loans. The buy-and-hold system features no loan sales, by assumption. Overall, this analysis illustrates both that the introduction of CLOs is socially beneficially overall but also motivates significantly restricting the quantity of low-quality assets they sell during downturns.

Table 3: Loan Prices and Intermediary Leverage Across Financial Systems

Variables	**CLOs**	**Buy-and-Hold**	**Traditional Banks**	Social Optimum
Safe Debt Quantity d_0	0.596	0.514	0.564	0.570
Loan Price p_0	0.900	0.900	0.894	0.902
Frac. Bad Loans Sold	0.432	0	0.542	0.204

The Role of Asset Illiquidity. Next, we examine how the differences across these financial systems as we change the parameter κ that determines how fire-sales $s_{f_l,2}$ impact the fire-sale discount $D(s_{f_l,2})$. We plot our results as a function of κ in figure 4. First, note that when κ is low, safe debt issuance d_0 is similar for CLOs and traditional banks, since the impact of fire sales is minimal. When κ becomes very high, CLO issuance of risk-free debt converges towards that of a buy-and-hold securitization. The banking system, even though

it has the option not to sell assets, results in strictly less debt issuance than a buy-and-hold securitization when κ is sufficiently high. This is because the privately-optimal choice to sell loans results in fire sale discounts, and these discounts constrain the ability of banks to issue debt against assets held to maturity. This relies crucially on the fact that banks must remain mark-to-market solvent unlike CLOs and hence are severely harmed by fire-sale discounts. The socially optimal financial system has modestly lower risk-free debt issuance than the unregulated CLO at all values of κ. This is because regulation causes more loans to be held to maturity, and selling bad loans ex post allows the CLO to have higher leverage ex ante.

In terms of increasing the quantity of risk-free debt d_0, CLOs are most useful when the degree of illiquidity κ is moderate. When assets are extremely liquid, banks can hold and sell them directly. When assets are extremely illiquid, CLOs have little or no advantage over buy-and-hold securitization. This illustrates why CLOs are active in the moderately liquid market of leveraged loans to firms. Treasury bonds have no need to be securitized, and mortgages which are too small to trade in a securities market are securitized by vehicles that hold assets to maturity.

We examine how ex ante loan prices p_0, which determines overall welfare, varies with the illiquidity parameter κ in the second panel. Except for a region when κ is very low and agents choose to sell 100% of their bad loans, we find that welfare does not change as κ varies except for the social optimum. This is because privately optimizing agents will always choose a quantity of fire sales that makes them indifferent between selling loans and holding them to maturity. As loans become more liquid, more of them are sold, resulting in the same fire-sale discounts. In contrast, in the financial system with optimally regulated CLOs, welfare grows as assets become more liquid. Only for extremely illiquid assets does the regulated system converge to the welfare of buy-and-hold securitization. This suggests that as the financial system becomes more developed and more assets trade in secondary markets, the motivation for regulating non-bank financial institutions could increase.

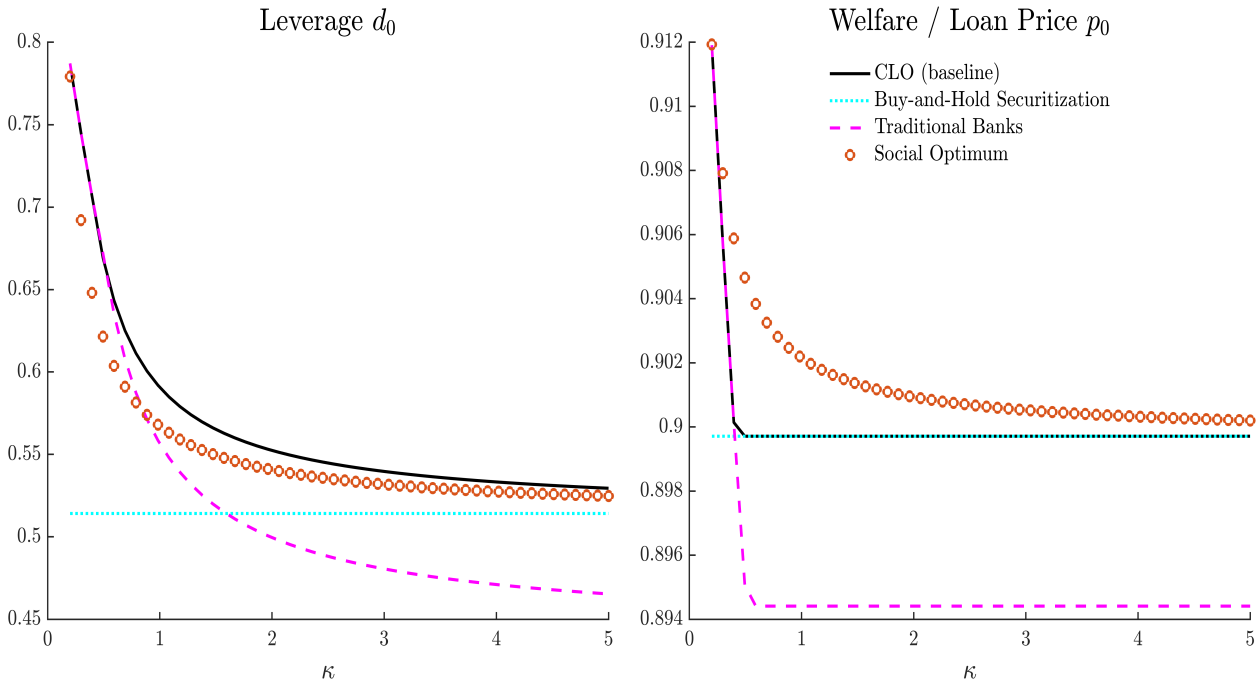


Figure 4: Comparative statics with respect to fire sale cost κ in baseline CLO financial system (solid black), buy-and-hold securitization (dotted cyan), traditional banking (dashed magenta), and the CLO system with optimal financial regulation (red circles).

5 Dynamic Model of CLO Portfolio Choice

In this section, we present a dynamic model of CLO portfolio choice which replicates our key result that CLOs actively remove risk from their portfolios in bad states of the world. This occurs even though CLOs can potentially default on thier debt, giving their equity investors a possible incentive to gamble in bad states of the world. In the model, CLOs rebalance their portfolios over time, subject to realistic overcollateralization and interest-coverage covenants, and CLOs can potentially default on their outstanding debt. In appendix C.1, we show our calibration which features significant cross-sectional and time-series variation in expected returns for loan investors, consistent with the sizable risk premia in the leveraged-loan market.

CLO Assets. CLOs can invest in leveraged loans, which are debt claims backed by cash flows generated by exogenous firms. Firm i generates a cash flow $f_t^i\left(Z_t, z_t^i\right)$ that depends on an aggregate state Z_t^i and an idiosyncratic state z_t^i that is i.i.d. across firms. These

states have Markov transition laws $\pi(Z_{t+1}|Z_t)$ and $\pi(z^i_{t+1}|z^i_t)$. Each loan owes a payment $r_l + (1+\delta_L)$ per unit of face value in each period and decays geometrically to have a fraction $\delta_L < 1$ of today's face value in the next period. Firm i defaults if $(r_l + (1-\delta_L)) > f^i_t$. If a loan defaults, the CLO obtains a liquidation value of a fraction $1-\chi$ of the present value of the firm's future cash flows. Non-defaulted loans can be bought and sold at a price $p_t(z^i_t)$ at time t. Let $ND_t(z^i_t)$ equal 1 if a firm i in state z^i_t is not in default at time t and 0 otherwise.

CLO's Problem. A CLO chooses a portfolio $Q^{CLO}_t(z^i_{t-1})$ of loans at each time t. It starts period t owning $Q^{CLO}_{t,-}(z^i_t) = \sum_{z^i_{t-1}} Q^{CLO}_{t-1}(z^i_{t-1})\pi(z^i_t|z^i_{t-1})$ quantity of loans in state z^i_t, where $Q^{CLO}_{t-1}(z^i_{t-1})$ is the loan portfolio chosen at time $t-1$. In addition, the CLO owes a face value B_t of debt, which pays an interest rate r_{CLO} and geometrically declines at rate δ_L. The CLO owes a payment $(r_{CLO} + (1-\delta_L))B_t$ on its debt at time t. CLOs obtain interest income $int^{CLO}_t = (r_l + (1-\delta_L))\sum_{z^i_t} ND_t(z^i_t)Q^{CLO}_{t,-}(z^i_t)$ from their holdings of non-defaulted loans, which finances their debt payments and dividends. CLOs are able to pay a dividend if they satisfy an "overcollateralization test" where their face value of non-defaulted loan holdings must be greater than $(1+\lambda_{OC})$ times their outstanding debt owed and an "interest coverage test" where their income must be greater than $(1+\lambda_{IC})$ times the payment they owe to their debtholders. In addition, the CLO avoids default if its interest income is greater than the interest owed on its debt. If we let $OCIC_t$ and ND^{CLO}_t respectively equal 1 when the CLO satisfies its covenants and avoids default and equal 0 otherwise, we have that

$$OCIC_t = \left\{ \frac{\sum_{z^i_t} Q^{CLO}_{t,-}(z^i_t)ND_t(i)}{1+\lambda_{OC}} > (1+r_{CLO})B_t \right\} * \left\{ \frac{int^{CLO}_t}{1+\lambda_{IC}} > (r_{CLO} + (1-\delta_L))B_t \right\}$$
$$ND^{CLO}_t = \left\{ int^{CLO}_t > (r_{CLO} + (1-\delta_L))B_t \right\}. \tag{42}$$

The CLO pays a dividend $\delta^{e,CLO}_t = OCIC_t[int^{CLO}_t - (r_{CLO} + (1-\delta_L))B_t]$ when its covenants are satisfied and otherwise uses its entire income to pay down its debt. The CLO maximizes the present value of dividends paid out to its equity-holders, who discount future cash flows at

the rate R_e. This yields the following expression of for the CLO's value function $V(A_t, B_t, Z_t)$ over its assets A_t, debt B_t, and state of the world Z_t

$$V(A_t, B_t, Z_t) = max_{Q_t^{CLO}(z_t^i)} \left[\frac{\mathbb{E}_t ND_{t+1}^{CLO}[\delta_{t+1}^{e,CLO} + V(A_{t+1}, B_{t+1}, Z_{t+1})]}{1+R_e} \right], \tag{43}$$

subject to the budget constraint for its portfolio $Q_t^{CLO}(z_t^i)$ and transition law for its debt B_t

$$\sum_{z_t^i} p_t(z_t^i) Q_t^{CLO}(z_t^i) = A_t = \sum_{z_{t-1}^i, z_t^i} \pi(z_t^i | z_{t-1}^i) Q_{t-1}^{CLO}(z_{t-1}^i)[(ND_t(z_t^i) p_t(z_t^i) \delta_L + (1 - ND_t(z_t^i))liq]$$

$$B_t = \delta_L B_{t-1} OCIC_t + (1 - OCIC_t)[(1 + r_f + sp^B) B_{t-1} - int_t^{CLO}], \tag{44}$$

as well as the definitions of $int_t^{CLO}, OCIC_t, ND_t^{CLO}, \delta_t^{e,CLO}$ and evolution of Z_t.

5.1 Results

Figure 5 shows how a CLO's marginal value of assets $\frac{\partial V}{\partial A}$ varies with the CLO's leverage $\frac{B}{A}$ and the state of the economy Z. In the first panel, this marginal value first increases with the CLO's leverage before finally decreasing once leverage reaches extremely high values. Outside of this extreme leverage region, the CLO is willing to pay more for assets that pay out when the CLO is performing poorly. That is, the CLO acts as if it is risk averse. However, once a CLO has entered an extreme region where default is likely, any payoff provided by the CLO's portfolio is primarily going to be paid to its creditors. For such extreme states, the CLO's default risk induces it to become risk loving rather than risk averse, preferring assets that pay relatively less in these most extreme states. Because this risk-loving region requires the CLO to have leverage near 150%, the design of CLOs successfully dis-incentivizes "risk-shifting": taking of risks by the CLO that harms the payout on the CLO's debt.

The second panel shows how CLOs' marginal value of assets varies with the aggregate state of the world Z. The lower the level of Z, the higher the expected return on holding loans, increasing the CLO's marginal value of funds. The CLO's marginal value of funds

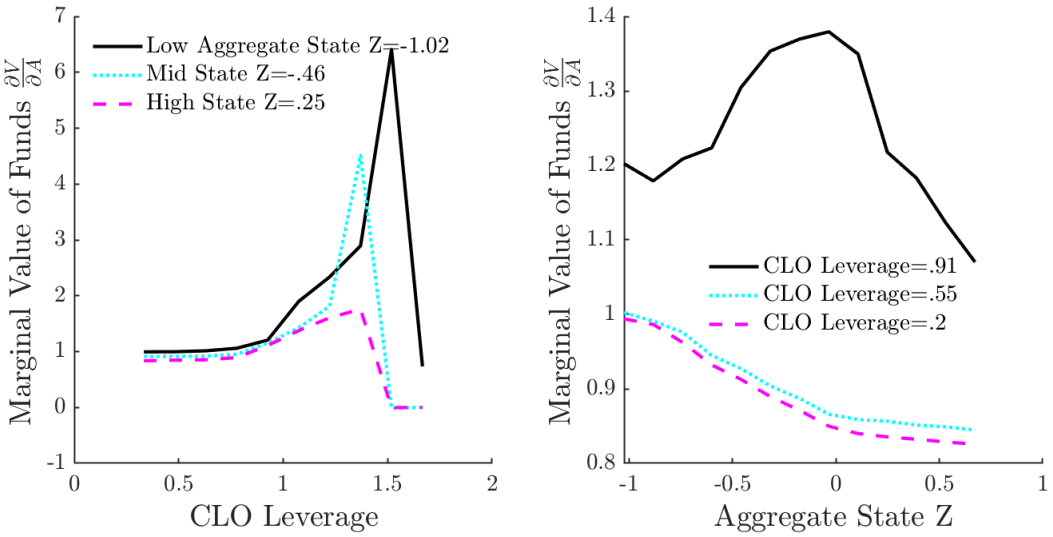


Figure 5: Left panel: marginal value of CLO assets as a function of CLO leverage for different aggregate states. Right panel: marginal value of CLO assets as a function of the aggregate state for different levels of leverage.

varies with Z even when its leverage equals .2, where CLO default is almost impossible. When the CLO reaches a high level of leverage .91, a second force appears: the CLO's is more likely to default at a given leverage ratio when the return on investing in loans is lower. As a result, the CLO's marginal value of funds initially increases in the state Z, since funds received at higher levels of Z help the CLO avoid default or covenant violations.

Table 4 shows how these changes in the CLO's marginal value of funds are reflected in its overall portfolio choices. We measure the risk of the CLO's portfolio with its "tilt": the covariance between the CLO's portfolio share in an asset and the value z_t^i of its idiosyncratic quality. We report the difference between this covariance and the same covariance evaluated on an "index" portfolio given by the stationary distribution of all z_t^i, as if the CLO simply owned the overall leveraged loan market. A positive (negative) value of this tilt implies that the CLO is actively choosing a more (less) risky portfolio than the overall market.

We see that CLOs generally prefer safe portfolios, and this preference for safety initially increases with CLO leverage. However, once CLO leverage becomes extremely high, in the same states of the world where $\frac{\partial V}{\partial A}$ is lowest, the CLO starts to actively choose to hold riskier

Tilt of CLO Portfolio Choice as Function of Leverage and Aggregate State Z

CLO Leverage	$Z = -0.74$	$Z = -0.46$	$Z = 0.11$
Leverage ≤ 0.70	0.118	0.107	0.064
$0.70 <$ Leverage ≤ 0.97	0.120	0.120	0.082
$0.97 <$ Leverage ≤ 1.23	0.128	0.145	0.082
Leverage > 1.23	-0.108	0.043	-0.014

State Z	Lev $= 0.20$	Lev $= 0.55$	Lev $= 0.91$
$Z \leq -0.46$	0.114	0.114	0.116
$-0.46 < Z \leq -0.03$	0.078	0.078	0.091
$-0.03 < Z \leq 0.39$	0.021	0.019	0.028
$Z > 0.39$	0	-0.018	-0.030

Table 4: Tilt is defined as the covariance between the CLO's portfolio share on an asset and the value of its state z_t^i, minus this same quantity evaluated on the overall index of leveraged loans. A positive (negative) tilt reflects the CLO actively choosing a safe (risky) portfolio.

loan portfolios. Outside of the most severe financial distress, we see that CLOs reduce the risk of their portfolio holdings when leverage is elevated. In the second panel, we see also that CLOs tilt toward safe portfolios also when the aggregate state of the economy Z is the worst. As the economy improves, the CLO chooses a riskier portfolio. Like in our theoretical model, CLOs reduce the risk of their portfolios in bad times, even though this more realistic model provides the CLOs with potential incentives to do the opposite.

6 Conclusion

We develop a theory in which CLOs emerge as the optimal financial structure for holding loans that trade in an illiquid market. By financing themselves with long-term safe debt and using covenants that do not force mark-to-market liquidation, CLOs can weather temporary price declines while still issuing large amounts of safe assets. Banks, in turn, hold only CLO debt, avoiding direct exposure to loan fire sales that could otherwise trigger a run. Compared to a traditional banking system, this division of roles improves welfare and financial stability, and welfare and stability increase even more when CLOs are optimally regulated.

Our model is unique in that it shows how the structure of a specific non-bank financial intermediary can be derived as the solution to a particular economic problem. CLOs differ both from banks, who tend to have long lending relationships, and traditional securitization vehicles, which hold a fixed pool of assets. Unlike, for example, the Collateralized Debt Obligations that contributed to the 2008 subprime crises, CLOs buy and sell loans over time, which mitigates for CLOs the CDO agency problem of intentionally choosing to securitize bad assets. As a result, our model focuses not on the information and monitoring frictions at the heart of traditional intermediation theory but on the empirically documented trading frictions in the secondary market for loans. In a model with such trading frictions, we both explain the structure of CLOs positively and can coherently evaluate the welfare benefits of CLOs normatively. We show that CLOs improve on a traditional banking system and are not just regulatory arbitrage, even though there is also reason to regulate CLOs.

References

Acharya, V. V., Cetorelli, N., and Tuckman, B. (2024). Where do banks end and nbfis begin? Technical report, National Bureau of Economic Research.

Acharya, V. V. and Rajan, R. (2024). Liquidity, liquidity everywhere, not a drop to use: Why flooding banks with central bank reserves may not expand liquidity. *The Journal of Finance*, 79(5):2943–2991.

Benmelech, E., Dlugosz, J., and Ivashina, V. (2012). Securitization without adverse selection: The case of clos. *Journal of Financial Economics*, 106(1):91–113.

Berndt, A., Douglas, R., Duffie, D., and Ferguson, M. (2018). Corporate credit risk premia. *Review of Finance*, 22(2):419–454.

Bhardwaj, A., Ge, S., and Mukherjee, S. (2025). Does loan securitization expose borrowers to non-bank investor shocks?—evidence from insurers. Technical report, National Bureau of Economic Research.

Bord, V. M. and Santos, J. A. (2015). Does securitization of corporate loans lead to riskier lending? *Journal of Money, Credit and Banking*, 47(2-3):415–444.

Buchak, G., Matvos, G., Piskorski, T., and Seru, A. (2018). Fintech, regulatory arbitrage, and the rise of shadow banks. *Journal of financial economics*, 130(3):453–483.

Chodorow-Reich, G., Ghent, A., and Haddad, V. (2021). Asset insulators. *The Review of Financial Studies*, 34(3):1509–1539.

Cordell, L., Roberts, M. R., and Schwert, M. (2021). Clo performance. Technical report, National Bureau of Economic Research.

Dang, T. V., Gorton, G., Holmström, B., and Ordonez, G. (2017). Banks as secret keepers. *American Economic Review*, 107(4):1005–29.

Dávila, E. and Korinek, A. (2018). Pecuniary externalities in economies with financial frictions. *The Review of Economic Studies*, 85(1):352–395.

DeMarco, L., Liu, E., and Schmidt-Eisenlohr, T. (2020). Who owns us clo securities? an update by tranche.

DeMarzo, P. M. (2005). The pooling and tranching of securities: A model of informed intermediation. *The Review of Financial Studies*, 18(1):1–35.

Diamond, D. W. (1984). Financial intermediation and delegated monitoring. *The review of economic studies*, 51(3):393–414.

Diamond, D. W. and Dybvig, P. H. (1983). Bank runs, deposit insurance, and liquidity. *Journal of political economy*, 91(3):401–419.

Diamond, D. W. and Rajan, R. G. (2001). Liquidity risk, liquidity creation, and financial fragility: A theory of banking. *Journal of political Economy*, 109(2):287–327.

Diamond, W. (2020). Safety transformation and the structure of the financial system. *The Journal of Finance*, 75(6):2973–3012.

Diamond, W., Jiang, Z., and Ma, Y. (2024). The reserve supply channel of unconventional monetary policy. *Journal of Financial Economics*, 159:103887.

Elkamhi, R., Li, R., and Nozawa, Y. (2024). A benchmark for collateralized loan obligations. *Management Science*.

Elkamhi, R. and Nozawa, Y. (2022). Fire-sale risk in the leveraged loan market. *Journal of Financial Economics*, 146(3):1120–1147.

Falasconi, L. (2025). Bailouts, bank regulation and risk-taking: A general-equilibrium exposition. *working paper*.

Fleckenstein, Q., Gopal, M., Gutierrez Gallardo, G., and Hillenbrand, S. (2020). Nonbank lending and credit cyclicality. *NYU Stern School of Business*.

Foley-Fisher, N., Heinrich, N., and Verani, S. (2023). Are us life insurers the new shadow banks? *Available at SSRN 3534847*.

Gorton, G. and Pennacchi, G. (1990). Financial intermediaries and liquidity creation. *The Journal of Finance*, 45(1):49–71.

Griffin, J. M. and Nickerson, J. (2023). Are clo collateral and tranche ratings disconnected? *The Review of Financial Studies*, 36(6):2319–2360.

Hanson, S. G., Shleifer, A., Stein, J. C., and Vishny, R. W. (2015). Banks as patient fixed-income investors. *Journal of Financial Economics*, 117(3):449–469.

He, Z. and Li, J. (2022). Intermediation via credit chains. Technical report, National Bureau of Economic Research.

Irani, R. M., Iyer, R., Meisenzahl, R. R., and Peydro, J.-L. (2021). The rise of shadow banking: Evidence from capital regulation. *The Review of Financial Studies*, 34(5):2181–2235.

Krishnamurthy, A. and Vissing-Jorgensen, A. (2012). The aggregate demand for treasury debt. *Journal of Political Economy*, 120(2):233–267.

Kundu, S. (2023). The externalities of fire sales: Evidence from collateralized loan obligations. *ESRB: Working Paper Series 2023/141*.

Kundu, S. (2024). Financial covenants and fire sales in closed-end funds. *Management Science*, 70(2):860–884.

Loumioti, M. and Vasvari, F. P. (2019). Consequences of clo portfolio constraints. *Available at SSRN 3371162*.

Luck, S. and Schempp, P. (2023). Inefficient liquidity creation. *Journal of financial intermediation*, 53:100996.

Nadauld, T. D. and Weisbach, M. S. (2012). Did securitization affect the cost of corporate debt? *Journal of financial economics*, 105(2):332–352.

Nagel, S. (2016). The liquidity premium of near-money assets. *The Quarterly Journal of Economics*, 131(4):1927–1971.

Rouwenhorst, K. G. (1995). Asset pricing implications of equilibrium business cycle models. *Frontiers of business cycle research*, 1:294–330.

Shivdasani, A. and Wang, Y. (2011). Did structured credit fuel the lbo boom? *The Journal of Finance*, 66(4):1291–1328.

Shleifer, A. and Vishny, R. (2011). Fire sales in finance and macroeconomics. *Journal of economic perspectives*, 25(1):29–48.

Stein, J. C. (2012). Monetary policy as financial stability regulation. *The Quarterly Journal of Economics*, 127(1):57–95.

Van Binsbergen, J. H., Diamond, W. F., and Grotteria, M. (2022). Risk-free interest rates. *Journal of Financial Economics*, 143(1):1–29.

Walsh, A. B., Narayanan, K. R., and Kanouse, S. (2023). Understanding collateralized loan obligations (clos). Technical report, Guggenheim Investments.

Xu, C. C. (2025). The value of contingent liquidity from banks to nonbank financiers. *Available at SSRN 5084953*.

Xu, D. (2023). Portfolio dynamics and the supply of safe securities. Technical report, Working Paper.

A Appendix

The appendix is organized as follows. Appendix A.1 provides proofs of results that are claimed in the main text, and appendix A.2 gives closed-form expressions for objects in this model that are too involved for the main text. Appendices A.3-A.6 provide additional theoretical results and extensions that document the robustness of the model's key results. Appendices B and C respectively present the calibrations of our benchmark model and our quantitative model from section 5.

A.1 Proofs of Results

Lemma 1.

1. At time 2 every asset makes a risk-free payoff at time 3. High-quality loans pay 1, and low-quality loans pay the amount δ_{f_l}, which equals 1 except when state B_2 is realized (then $\delta_{f_l} = f_l$ and is known at time 2). Depositors are therefore willing to hold these short-term risk-free assets directly at the rate of return R_d. A high-quality loan thus has price $\frac{1}{1+R_d}$, while a low-quality loan has price $\frac{\delta_{f_l}}{1+R_d}$.

Next, at time 1 consider an asset that will trade at $\frac{1}{1+R_d}$ in period 2 (this includes all assets in state G_1 and all high-quality loans in state B_1). If such an asset were sold to the outside financier at time 1, its price would be $\frac{1-D(s_{1,2})}{(1+R_a)(1+R_d)}$, whereas the bank could instead raise the larger amount $\frac{1-D(s_{1,2})}{(1+R_d)^2}$ in deposits backed by that same asset. Hence no part of the asset is sold, $s_{1,2} = 0$, and its time-1 price is $\frac{1}{(1+R_d)^2}$.

2. Suppose the bank holds at time t an asset that earns the risk-free rate R_d from t to $t+1$ and pays a positive dividend at $t+1$. The time-0 present value of retaining the asset and paying the dividend at $t+1$ is $\frac{1+R_d}{(1+R_e)^{t+1}}$, while selling the asset at t and distributing the proceeds immediately has present value $\frac{1}{(1+R_e)^t}$, which is strictly larger. Consequently, once aggregate uncertainty is resolved, the bank distributes the largest dividend possible subject to repaying its debt.

Lemma 2.

1. By Lemma 1, the bank pays the maximum dividend once it reaches time 2. Fix $q^B_{f,1}$ in state B_1 and assume the no-run constraint is slack. Issuing one more unit of deposits raises the time - 1 dividend by 1 and lowers the time - 2 dividend by $1 + R_d$. The time-0 present value of this change equals

$$\tfrac{1}{1+R_e} \;-\; \tfrac{1+R_d}{(1+R_e)^2} \;>\; 0,$$

so the bank continues issuing deposits at time 1 until its mark-to-market constraint binds.

2. Suppose, to the contrary, the bank pays a positive dividend in the bad state at time 1, so dividends are positive in both states at that date. If instead the bank had issued additional deposits at time 0, paid a larger immediate dividend, and then reduced the dividend at time 1 to repay those deposits, the net present value per unit would be

$$1 \;-\; \tfrac{1+R_d}{1+R_e} \;>\; 0.$$

Hence in state B_1 the dividend must be zero.

Derivation of equation (24)**.**

From the bank's no-run constraint, the greatest payment it can pledge to depositors at time 2 after state B_1 is realized equals

$$\sum_f (1 - D(s_{f,2}))\, \tfrac{f}{1+R_d}\, q^B_{f,1}.$$

The portfolio's market value is $\sum_f \frac{f}{1+R_d}\, q^B_{f,1}$ in state B_2 and $\sum_f \frac{q^B_{f,1}}{1+R_d}$ in state G_2. The bank therefore pays the maximum dividend in each of these states, namely

$$\tfrac{\sum_f f\, q^B_{f,1}}{1+R_d} \;-\; \tfrac{\sum_f (1-D(s_{f,2}))\, f\, q^B_{f,1}}{1+R_d} \quad \text{in } B_2,$$

and

$$\frac{\sum_f q^B_{f,1}}{1+R_d} \;-\; \frac{\sum_f (1-D(s_{f,2}))f\, q^B_{f,1}}{1+R_d} \quad \text{in } G_2.$$

Similarly, the portfolio delivers $\frac{Q^B_0}{(1+R_d)^2}$ in state G_1, of which $(1+R_d)d^B_0$ is required for deposit repayment, leaving the remainder as a dividend. The bank pays no dividend in state B_1 and issues the maximum deposit issuance at date - 0 is

$$\frac{\sum_f (1-D(s_{f,2}))f\, q^B_{f,1}}{(1+R_d)^2}.$$

Collecting the dividends across all states yields the objective function (24), while the deposit issuance condition gives the budget constraint (25).

Lemma 3.

1. The proof is nearly identical to the proof in part 2 of Lemma 1. Once aggregate risk is resolved, all assets compound at rate R_d, while the investor of CLO's equity discounts the future at the rate $R_e > R_d$, and therefore, $(1+R_e)^\tau > (1+R_d)^\tau$. Dividing both sides by $(1+R_3)^{t+\tau}$ yields that paying a dividend of 1 at time t instead of $(1+R_d)^\tau$ at time $t+\tau$ has an excess time-0 present value of

$$\frac{1}{(1+R_e)^t} - \frac{(1+R_d)^\tau}{(1+R_e)^{t+\tau}} \;>\; 0.$$

2. This is similar to part 1 of Lemma 2. Holding the CLO's asset holdings fixed, future dividends pledged to debt are discounted at R_d, whereas dividends to shareholders are discounted at the strictly higher rate R_e. For any fixed cash-flow stream, the CLO should therefore issue the maximum feasible amount of risk-free debt.

3. This parallels part 2 of Lemma 2. If the CLO paid a positive dividend ε in both states at time 1, it could instead invest that cash flow to obtain a risk-free payoff $\varepsilon(1+R_d)^2$ at time 3, against which it could issue a risk-free bond worth $\dfrac{\varepsilon(1+R_d)^2}{(1+R_d)^3}$ at time 0—strictly greater than the time-0 value $\dfrac{\varepsilon}{1+R_e}$ of the time-1 dividend. Hence the dividend in state B_1 must

be zero.

Derivation of Equation (32)**.** If the CLO holds a portfolio $q^C_{f,1}$ in the bad state at time 1, its lowest possible value at time 2 (state B_2) is

$$\sum_f \tfrac{q^C_{f,1} f}{1+R_d},$$

allowing it to repay $\sum_f q^C_{f,1} f$ on its debt. If instead state G_2 occurs, the portfolio is worth $\sum_f \frac{q^C_{f,1}}{1+R_d}$, permitting a dividend of $\sum_f \frac{q^C_{f,1}(1-f)}{1+R_d}$.

In state G_1, all loans pay 1 at time 3, so the portfolio's value is $\frac{Q^C_0}{(1+R_d)^2}$. The corresponding dividend is

$$\tfrac{Q^C_0}{(1+R_d)^2} - \sum_f \tfrac{f\, q^C_{f,1}}{(1+R_d)^2}.$$

These expressions yield the dividend terms in equation 32.

Because the CLO pays no dividend in state B_1, its portfolio value in that state, $Q^C_0 \sum_f \pi(f) p^C_{f,1}$, equals the cost $\sum_f p_{f,1}(B_1)\, q^C_{f,1}$ of the assets it purchases, producing equation (33).

A.2 Explicit Expressions for Loan Prices and Quantities

Equating $p_0^{C,\mathrm{FS}}$ and $p_0^{C,\mathrm{HTM}}$ gives

$$\begin{aligned} 0 \;&= \pi(f_l)\big(f_l - p_{f_l,1}(1+R_d)^2\big)\left[\tfrac{1}{(1+R_d)^3} - \tfrac{\Pr(G_1)}{(1+R_e)(1+R_d)^2}\right] \\ &+ \;\tfrac{\Pr(G_2)\Pr(B_1)}{(1+R_e)^2}\left[\tfrac{(1-f_l)\,\pi(f_l)}{1+R_d}\right]. \end{aligned} \tag{A.1}$$

The implied loan-sale price is therefore

$$p_{f_l,1} \;=\; \frac{f_l\left[\dfrac{1}{(1+R_d)^2} - \dfrac{\Pr(G_1)}{(1+R_e)(1+R_d)}\right] + \dfrac{\Pr(G_2)\Pr(B_1)}{(1+R_e)^2}\,(1-f_l)}{(1+R_d)^2\left[\dfrac{1}{(1+R_d)^2} - \dfrac{\Pr(G_1)}{(1+R_e)(1+R_d)}\right]}. \tag{A.2}$$

Using the outside financier's first-order condition (equation 3.1),

$$p_{f_l,1} = \frac{(1-D(s_{f_l,2}))\,\mathrm{E}\left[p_{f_l,2}\right]}{(1+R_a)} = (1-D(s_{f_l,2}))\,\frac{f_l+\Pr(G_2)(1-f_l)}{(1+R_a)(1+R_d)}, \tag{A.3}$$

$$s_{f_l,2} = D^{-1}\left(1-\frac{(1+R_d)(1+R_a)\,p_{f_l,1}}{f_l+\Pr(G_2)(1-f_l)}\right). \tag{A.4}$$

The economy admits a unique equilibrium with an interior solution for the loan-sale share $s_{f_l,2}$ provided that equation (A.4) yields a value $0 < s_{f_l,2} < 1$, under the assumption that the discount function $D(\cdot)$ is strictly increasing.

A.3 Economy with the Potential for Systemic Bank Runs

This appendix extends our analysis of how depositors' demand for risk-free assets imposes a borrowing constraint on banks. Depositors will provide funds only if they are assured their deposits will be repaid in full, even in the event of a bank run. We study a stricter version of the no-run constraint in the main text. Here, banks must remain solvent during a system-wide run, where the liquidation of assets increases the equilibrium fire-sale discounts. This stricter constraint yields a version of our model where maturity transformation by banks is costly, so that the yield on AAA debt issued by CLO's is strictly above the bank's cost of deposit financing. Nevertheless, in this extension of our model, CLOs still emerge in equilibrium and finance themselves with AAA debt held by banks.

We consider a stricter no-run constraint by requiring that banks be capable of repaying depositors even in the event of a systemic run affecting the entire banking system. For expositional clarity, we restrict attention to the case in which such a systemic run may occur only at time 2. Here, we work under the regularity condition that $[1 - D(s_{f,t} + Q)]Q$ is increasing in Q, so that liquidating a larger quantity of assets always provides banks with a larger quantity of funds. If the bank holds a quantity $q^B_{f,1}$ of assets of quality f at time 2,

the no-run constraint now becomes

$$\sum_f p_{f,2}(1 - D(s_{f,2} + q^B_{f,1}))q^B_{f,1} \geq d_1(1 + R_d). \tag{A.5}$$

A key implication of this constraint is that, even if no fire sales of an asset with quality f occur in equilibrium, the potential fire-sale discount from liquidating a quantity $q^B_{f,1}$ during a run at time 2 still limits a bank's capacity to issue deposits. As we show below, this will result in a strictly higher risk-free rate at which CLOs borrow from banks than the bank's deposit rate R_d. Nevertheless, CLOs will still endogenously emerge in the equilibrium of this version of our economy.

The bank's objective problem is identical to equation (5) in the main text

$$\max_{Q^B_0,\, d^B_t,\, q^B_{f,t}} \left[-p_0 Q^B_0 + d^B_0 + \mathrm{E}\left[\sum_{t=1}^{3} \tfrac{\delta^B_t}{(1+R_e)^t} \right] \right]. \tag{A.6}$$

subject to the same budget constraints,

$$\overbrace{\delta^B_t}^{\text{Dividend payout}} = \overbrace{\sum_f p_{f,t}\big(q^B_{f,t-1} - q^B_{f,t}\big)}^{\text{Net sale of assets}} + \overbrace{d^B_t - (1 + R_d)d^B_{t-1}}^{\text{Net deposit borrowing}} \geq 0, \qquad t = 1, 2, \tag{A.7}$$

$$\overbrace{\delta^B_3}^{\text{Dividend payout}} = \overbrace{\sum_f \delta_f\, q^B_{f,2}}^{\text{Final asset payoff}} - \overbrace{(1 + R_d)d^B_2}^{\text{Final deposit repayment}} \geq 0, \tag{A.8}$$

the evolution of loan quality at time 1, $q^B_{f,0} = \pi(f)Q^B_0$, and a new, stricter solvency constraint

$$\overbrace{(1 + R_d)d^B_t}^{\text{Payment due to depositors at } t+1} \leq \overbrace{\sum_f \big(1 - D_f(Q^B_{f,t+1} + s_{f,t+1})\big)\, p_{f,t+1}\, q^B_{f,t}}^{\text{Fire-sale value of bank assets in a systemic run}}, \qquad t = 1. \tag{A.9}$$

Here, $Q^B_{f,2}$ refers to the aggregate quantity of sales that occur in a run at time 2, which an individual bank takes as given. However, in equilibrium we have the market-clearing condition that $q^B_{f,1} = Q^B_{f,2}$. Because the bank takes the discount D_f as given, we will analyze

this problem where the $D_f(.)$ are exogenous constants that depend on the aggregate state $D_f(G_1), D_f(G_2), D_f(B_2)$ before we then consider their equilibrium values. Moreover, we will take the discount $D_f(G_1) = D(G_1)$ in the good state to be equal for all loan qualities f as we verify below.

As in the main text, once uncertainty is realized at time 2 we have that $p_{f,2} = \frac{\delta_f}{(1+R_d)}$. Here, δ_f is the dividend at time 3 of an asset of quality f, equal to 1 except in states G_1 or G_2 and f in state B_2. In addition, because the bank's shareholders discount future cash flows at the rate $R_e > R_d$, the bank will pay the largest possible dividend at time 2 without defaulting. In addition, we will work under the assumptions that we verify below. First, the bank pays a positive dividend in state G_1. Second, in state B_1, $s_{f,2}$ is positive only for low quality assets and is 0 in the good state.

The bank's no run constraint at time 2 can therefore be written as

$$\sum_f q^B_{f,1}\delta_f \tfrac{(1-D_f)}{1+R_d} \geq d_1(1+R_d), \tag{A.10}$$

and the price of a loan held by the bank in state G_1 must satisfy the first-order condition

$$p_1(G_1) = \tfrac{1-D(G_1)}{(1+R_d)^2} + \tfrac{D(G_1)}{(1+R_e)(1+R_d)}. \tag{A.11}$$

If the bank purchases a loan L at time 0 and firesells it at time 1, the FOC (under the assumption that dividends are paid in the good state) with respect to Q^B_0 gives the bank's willingness to pay at time 0 for a loan that it fire sells in time 1:

$$p_0^{L,FS} = \sum_f \pi(f)\left(p_{f,1}(B_1)\left(\tfrac{1}{1+R_d}\right) + \tfrac{p_{f,1}(G_1)-p_{f,1}(B_1)}{1+R_e}\right). \tag{A.12}$$

The bank will not pay dividends in state B_1 since it can instead use a positive cash flow in states B_1 and G_1 together to repay a deposit issued at time 0.

If instead, the bank buys a loan and holds it to maturity, it can borrow up to $\frac{(1-D_f(B_2))f}{(1+R_d)^3}$

without triggering a run in the worst state. A remaining dividend $D_f(B_2))f$ can be paid in this worst state and an additional $1-f$ in state G_2. On top of this, if the bank reaches state G_1, its borrowing capacity increases. The bank now can promise an additional $(1 - D_f(G_1)) - (1 - D_f(B_2))f$ of borrowing to repay at time 3 without triggering a run. The bank's willingness to pay for a loan it holds to maturity is therefore

$$p_0^{L,HTM} = \sum_f \pi(f) \Bigg(\tfrac{(1-D_f(B_2))f}{(1+R_d)^3} + \tfrac{D_f(B_2)f}{(1+R_d)(1+R_e)^2} + [1 - Pr(B_1)Pr(B_2)] \tfrac{1-f}{(1+R_d)(1+R_e)^2} + \tfrac{Pr(G_1)[(1-D_f(G_1))-(1-D_f(B_2))f]}{(1+R_e)(1+R_d)} \left(\tfrac{1}{(1+R_d)} - \tfrac{1}{(1+R_e)} \right) \Bigg). \tag{A.13}$$

For a loan which has $\pi(1) = 1$ so that it always has a risk-free payoff of 1, this becomes

$$p_0^{AAA,HTM} = \tfrac{(1-D_1(B_2))}{(1+R_d)^3} + \tfrac{D_1(B_2)}{(1+R_d)(1+R_e)^2} + \tfrac{Pr(G_1)[(D_1(B_2)-D_1(G_1)]}{(1+R_e)(1+R_d)} (\tfrac{1}{(1+R_d)} - \tfrac{1}{(1+R_e)}). \tag{A.14}$$

If $D_1(B_2) > D_1(G_1) \geq 0$, this implies that banks will finance long-term risk-free debt at a strictly higher interest rate than their deposit cost of capital.

Next, we consider whether a CLO financed with long-term safe debt at this "AAA cost of capital" will pay strictly more than a bank to hold long term loans. One unit of risk-free payoff promised by the CLO at time 3 allows it to raise funding at time 0 equal to $p_0^{AAA,HTM}$. This quantity is determined by the value of CLO's holdings of asset of quality f $q_{f,1}^C f$.

The CLO's objective function is the same as the equation A.37, and results in a similar simplified expression as equation (32), except for the CLO's borrowing costs. This is because CLOs are funded by long-term AAA-debt. Using $R_{AAA,2}$ to denote the discount rate of a AAA-rated note that is held for 2 periods. the CLO's objective function is now

$$\max_{Q_0^C,\, q_{f,1}^C \geq 0} p_0^{AAA,HTM} \sum_f q_{f,1}^C f - p_0 Q_0^C + \tfrac{\Pr(G_1) p_1(G_1)}{1+R_e} \left[(Q_0^C - \sum_f q_{f,1}^C f)) \right] + \tfrac{\Pr(G_2)\Pr(B_1)}{(1+R_e)^2} \left[\tfrac{\sum_f (1-f)\, q_{f,1}^C}{1+R_d} \right], \tag{A.15}$$

subject to the same budget constraint (equation 33) as in the main text.

The CLO's willingness to pay for a loan of quality f held to maturity is

$$p_0^{C,HTM} = f p_0^{AAA,HTM} + (1-f)\left(\frac{Pr(B_1)Pr(G_2)}{(1+R_e)^2(1+R_d)} + \frac{Pr(G_1)p_1(G_1)}{(1+R_e)}\right) \tag{A.16}$$

The bank's AAA cost of capital $p_1(G_1)$ for loans in state G_1 implies

$$\begin{aligned} p_0^{C,HTM} &= f p_0^{AAA,HTM} + \tfrac{1-f}{1+R_d}\left(\tfrac{Pr(B_1)Pr(G_2)}{(1+R_e)^2} + \tfrac{Pr(G_1)}{(1+R_e)}\left(\tfrac{1-D_1(G_1)}{1+R_d} + \tfrac{D_1(G_1)}{1+R_e}\right)\right) \\ &= f p_0^{AAA,HTM} + \tfrac{1-f}{1+R_d}\left(\tfrac{1-Pr(B_1)Pr(B_2)}{(1+R_e)^2} + \tfrac{Pr(G_1)[1-D_1(G_1)]}{1+R_e}[\tfrac{1}{1+R_d} - \tfrac{1}{1+R_e}]\right) \end{aligned} \tag{A.17}$$

The difference between this expression and a bank's value to hold this loan to maturity itself is

$$\begin{aligned} &\Big(f\left(\tfrac{(1-D_1(B_2))}{(1+R_d)^3} + \tfrac{D_1(B_2)}{(1+R_d)(1+R_e)^2} + \tfrac{Pr(G_1)[(D_1(B_2)-D_1(G_1)]}{(1+R_e)(1+R_d)}(\tfrac{1}{(1+R_d)} - \tfrac{1}{(1+R_e)})\right) \\ &+ \tfrac{1-f}{1+R_d}\left(\tfrac{1-Pr(B_1)Pr(B_2)}{(1+R_e)^2} + \tfrac{Pr(G_1)[1-D_1(G_1)]}{1+R_e}[\tfrac{1}{1+R_d} - \tfrac{1}{1+R_e}]\right)\Big) \\ &-\Big(\tfrac{(1-D_f(B_2))f}{(1+R_d)^3} + \tfrac{D_f(B_2)f}{(1+R_d)(1+R_e)^2} + [1-Pr(B_1)Pr(B_2)]\tfrac{1-f}{(1+R_d)(1+R_e)^2} \\ &+ \tfrac{Pr(G_1)[(1-D_f(G_1))-(1-D_f(B_2))f]}{(1+R_e)(1+R_d)}\left(\tfrac{1}{(1+R_d)} - \tfrac{1}{(1+R_e)}\right)\Big). \end{aligned} \tag{A.18}$$

This implies that the difference between the CLOs' willingness to pay $p_0^{C,HTM}(f)$ for a loan of quality f and a bank's willingness to pay $p_0^{B,HTM}(f)$ for the same loan is

$$\begin{aligned} p_0^{C,HTM}(f) - p_0^{B,HTM}(f) &= [D_f(B_2) - D_1(B_2)]f(\tfrac{1}{(1+R_d)^3} - \tfrac{1}{(1+R_d)(1+R_e)^2}) + \tfrac{Pr(G_1)}{(1+R_e)(1+R_d)} * \\ &(\tfrac{1}{1+R_d} - \tfrac{1}{1+R_e})[fD_1(B_2) + (1-f) - D_f(G_1) - [(1-f) - D_f(G_1) + D_f(B_2))f]] \\ &= \tfrac{f[D_f(B_2)-D_1(B_2)]}{1+R_d}[(\tfrac{1}{(1+R_d)^2} - \tfrac{1}{(1+R_e)^2}) - \tfrac{Pr(G_1)}{1+R_e}(\tfrac{1}{1+R_d} - \tfrac{1}{1+R_e})]. \end{aligned} \tag{A.19}$$

The final expression in equation A.19 has the same sign as $D_f(B_2) - D_1(B_2)$. If the low-quality loan suffers a greater fire-sale discount than high quality loans during a crisis, then

a CLO financed with long-term risk-free debt will pay strictly more to hold such loans than a bank. If instead these two discounts are equal, then a CLO and bank are willing to pay the same price. The following theorem summarizes our key result.

Proposition 6. *In the modified economy, where banks must maintain balance sheets that can withstand systemic runs affecting equilibrium asset prices (and not merely runs on an individual bank), the following hold:*

1. *The risk-free rate on CLOs' long-term debt is strictly above the deposit rate at which banks borrow (see equation A.14), provided that the fire-sale discount for risk-free loans satisfies $D_1(B_2) \geq D(G_1) > 0$.*

2. *If the fire-sale discount $D_f(B_2)$ for low-quality loans ($f = f_l$) is strictly greater than the discount for high-quality loans ($f = 1$), then CLOs that hold loans to maturity are willing to pay strictly more than banks to acquire such loans. If the two discounts are equal, banks and CLOs have the same willingness to pay for loans held to maturity.*

A.3.1 Determining Equilibrium Fire-sale Discounts

In the remainder of this section of the appendix, we determine the magnitude of the equilibrium fire-sale discounts that we take as given in section A.3. First, observe that in the good state G_1, by construction all loans are either sold to the outside financier or held to maturity by a bank or a CLO. Since the CLO's assets are risk-free, it operates with full leverage and effectively functions as a pass-through vehicle for the bank. It follows that $s_1 + q_1^B = 1$, yielding the discount $D(1)$ in the good state for assets in a run. Next, we provide conditions under which the bank or CLO sells assets in the good state G_1 in order to pay a positive quantity of dividends. If a quantity s_1 of assets is sold to the outside financier in the good state, the outside financier is willing to pay for an asset paying 1 at time 3

$$p_1(G_1) = \frac{1-D(s_1)}{(1+R_a)(1+R+d)}. \tag{A.20}$$

A positive quantity is sold if the expression with $s_1 = 0$ in equation A.21 is strictly greater than the price in equation A.11 with $D(G_1) = D(1)$. The equilibrium value of s_1 sets these two valuations equal.

Next, we determine the fire-sale discounts in the bad state B_2, where low and high-quality loans are no longer identical. Here, the outside financier is willing to pay

$$p_{f,1}(B_1) = \tfrac{[1-D(s_{f,2})](Pr(G_2)+Pr(B_2)f)}{(1+R_a)(1+R_d)} \tag{A.21}$$

for a loan of quality f. Given this price, if an interior solution is found where some but not all loans of quality f are sold to the outside financier, we must have jointly that

$$p_0^{FS}(f) = \left(p_{f,1}(B_1)\left(\tfrac{1}{1+R_d} - \tfrac{1}{1+R_e}\right) + \tfrac{p_1(G_1)-p_{f,1}(B_1)}{1+R_e}\right). \tag{A.22}$$

and for loans held to maturity by the CLO

$$\begin{aligned} p_0^{C,HTM}(f) =& f\left(\tfrac{(1-D_1(B_2))}{(1+R_d)^3} + \tfrac{D_1(B_2)}{(1+R_d)(1+R_e)^2} + \tfrac{Pr(G_1)[(D_1(B_2)-D_1(G_1)]}{(1+R_e)(1+R_d)}(\tfrac{1}{(1+R_d)} - \tfrac{1}{(1+R_e)})\right) \\ &+ \tfrac{1-f}{1+R_d}\left(\tfrac{1-Pr(B_1)Pr(B_2)}{(1+R_e)^2} + \tfrac{Pr(G_1)[1-D(G_1)]}{1+R_e}[\tfrac{1}{1+R_d} - \tfrac{1}{1+R_e}]\right). \end{aligned} \tag{A.23}$$

If a loan is held to maturity by a bank, it must satisfy

$$\begin{aligned} p_0^{B,HTM}(f) =& \tfrac{(1-D_f(B_2))f}{(1+R_d)^3} + \tfrac{D_f(B_2)f}{(1+R_d)(1+R_e)^2} + [1 - Pr(B_1)Pr(B_2)]\tfrac{1-f}{(1+R_d)(1+R_e)^2} \\ &+ \tfrac{Pr(G_1)[(1-D(G_1))-(1-D_f(B_2))f]}{(1+R_e)(1+R_d)}\left(\tfrac{1}{(1+R_d)} - \tfrac{1}{(1+R_e)}\right). \end{aligned} \tag{A.24}$$

Here, $D_f(B_2) = D_f(s_{f,2}(B_1) + q^B_{f,1}(B_1))$ for loans of any quality f, where $q^B_{f,1}(B_1)$ is the quantity of loans of quality f held by the bank at time 1 in state B_1. A positive quantity of CLOs will emerge in equilibrium if we have that $D_f(\pi(f))$ is greater for $f = f_l$ than for $f = 1$, since this would imply that low-quality loans would have a larger discount than high quality loans.

By proposition 6, the CLO will hold low-quality loans to maturity up until the point where the discount $D_f(B_2)$ is the same for high and low quality loans. If the CLO holds a quantity $q^C_{f_l,1}(B_1)$ of low quality loans, then these discounts become $D_1(\pi(1) + f_l q^C_{f_l,1}(B_1))$ for high-quality loans and $D_{f_l}(\pi(f_l) - q^C_{f_l,1}(B_1))$ for low quality loans. CLOs will either hold the quantity $q_{f_l,1}(B_1)$ of loans that equalizes these discounts, in which case the bank also holds a positive quantity of holds, or a corner solution will be reached where the bank holds no low-quality loans to maturity.

In an interior solution, the equation $D_1(\pi(1) + f q^C_{f_l,1}(B_1)) = D_f(\pi(f) - q^C_{f_l,1}(B_1))$ pins down the quantity $q^C_{f_l,1}(B_1)$ of low-quality loans held by the CLO. Given the resulting fire-sale discount in a run, the quantity $s_{f,2}(B_1)$ sold to the outside financier is determined by setting $p_0^{FS}(f) = p_0^{B,HTM}(f)$.

In a corner solution, $D_1(B_2) = D_1(\pi(1) + f(\pi(f_l) - s_{f_l,2}))$ and $D_{f_l}(B_2) = D_{f_l}(s_{f_l,2})$. The equilibrium fire-sale quantities are determined by setting $p_0^{C,HTM}(f) = p_0^{FS}(f)$ for both $f = f_l$ and $f = 1$.

In either type of equilibrium, CLOs emerge endogenously in equilibrium as in our benchmark model in the main text. We summarize our results in the following proposition.

Proposition 7. *Suppose that $D_f(\pi(f))$ is larger for $f = f_l$ than $f = 1$, so that in an economy without CLOs, the equilibrium fire sale discount is strictly greater for low-quality loans than high-quality loans in a systemic bank run. If so, a positive quantity of CLOs exists in equilibrium. There are two possible cases:*

1. A corner solution where all low-quality loans held to maturity are held by CLOs financed by issuing long-term risk-free debt.

2. An interior solution where banks and CLOs each hold some low quality loans.

A.4 Optimality of the Financial System with Banks and CLOs

In this appendix, we show that in a financial system with banks and CLOs, there is no benefit for any third type of intermediary to enter. To do so, we assume that asset prices

are consistent with an equilibrium where CLOs exist. Then, we show that any third type of intermediary who enters this economy is not able to make a strictly positive profit.

An intermediary I has access to the same financing opportunites as a bank or CLO: it can raise equity at time 0 and issue securities backed by the pool of assets that it purchases. The intermediary's objective function is to maximize its shareholder value

$$-e_0^I + \sum_{t=1}^{3} \mathrm{E}\frac{\delta_t^I}{(1+R_e)^t}, \tag{A.25}$$

where e_0^I is its equity issued at time 0 and δ_t^I is the dividend it pays at time t. The intermediary holds a quantity Q_0^I of loans at time 0 and $q_{f,t}^I$ of loans of quality f at time t. In addition, it issues an arbitrary security at time 0 that makes a possibly state-contingent payment d_t^I at time t backed by its loan holdings. This payoff can very with the realization of the aggregate shock G_1, G_2, B_1, B_2. Let $p_t^I(\{d_t^I\})$ be the price of the security issued by this intermediary at time t. The intermediary's problem is to maximize

$$p_0^I(\{d_t^I\}) - p_0 Q_0^I + \sum_{t=1}^{3} E\frac{\delta_t^I}{(1+R_e)^t}. \tag{A.26}$$

subject to the evolution of loan quality $Q_0^I \pi(f) = q_{f,0}^I$ and the budget constraints

$$\delta_t^I = \sum_f p_{f,t}[q_{f,t-1}^I - q_{f,t}^I] - d_t^I \geq 0 \quad t = 1, 2 \tag{A.27}$$

$$\delta_3^I = \sum_f q_{f,2}^I \delta_3^f - d_3^I \geq 0. \tag{A.28}$$

Once aggregate risk is realized at time 2 or in the good state at time 1, all financial assets earn a rate of return of R_d. Because this includes both the assets and liabilities of our intermediary, they make 0 profit by continuing to hold assets after aggregate risk is realized. The intermediary therefore chooses $d_3^I = \delta_3^I = d_2^I(G_1) = \delta_2^I(G_1) = 0$. We can therefore reduce

their problem to maximizing

$$p_0^I(\{d_t^I\}) - p_0 Q_0^I + \frac{Pr(G_1)\delta_1^I(G_1)+Pr(B_1)\delta_1^I(B_1)}{(1+R_e)} + \frac{Pr(B_1)[Pr(G_2)\delta_2^I(G_2)+Pr(B_2)\delta_2^I(B_2)]}{(1+R_e)^2}. \tag{A.29}$$

The price $p_0^I(\{d_t^I\})$ of the security issued by this intermediary comes from the fact that it will be sold to the CLO at time 0. This is because the CLO is willing to pay (weakly) more than any other investor for all assets. The CLO, then, can either sell the asset in the bad state B_1 at time 1 or hold it to maturity. We will show that in either case, our intermediary's profits cannot be strictly positive.

If the CLO holds the intermediary's security to maturity, it is worth

$$\begin{aligned} p_{0,HTM}^I(\{d_t^I\}) =& \frac{d_1^I(B_1)}{(1+R_d)} + \frac{d_2^I(B_2)}{(1+R_d)^2} + Pr(G_1)\frac{d_1^I(G_1) - d_1^I(B_1) - \frac{d_2^I(B_2)}{1+R_d}}{1+R_e} \\ &+ \frac{Pr(B_1)Pr(G_2)}{(1+R_e)^2}\left(d_2^I(G_2) - d_2^I(B_2)\right). \end{aligned} \tag{A.30}$$

The sum of this expression plus the present value of the intermediary's equity dividends is

$$\begin{aligned} & Pr(B_1)\frac{\sum_f p_{f,1}(B_1)[Q_0^I\pi(f) - q_{f,1}^I(B_1)] - d_1^I(B_1)}{1+R_e} + \frac{d_1^I(B_1)}{1+R_d} + \frac{d_2^I(B_2)}{(1+R_d)^2} \\ & + Pr(G_1)\left[\frac{d_1^I(G_1) - d_1^I(B_1) - \frac{d_2^I(B_2)}{1+R_d}}{1+R_e} + \frac{\frac{1}{(1+R_d)^2}Q_0^I - d_1^I(G_1)}{1+R_e}\right] \\ & + Pr(B_1)\left[Pr(B_2)\frac{\sum_f \frac{f}{1+R_d}q_{f,1}^I(B_1) - d_2^I(B_2)}{(1+R_e)^2} + Pr(G_2)\left[\frac{\frac{1}{1+R_d}\sum_f q_{f,1}^I(B_1) - d_2^I(G_2)}{(1+R_e)^2} + \frac{d_2^I(G_2) - d_2^I(B_2)}{(1+R_e)^2}\right]\right]. \end{aligned} \tag{A.31}$$

This is either weakly or strictly less than the value the CLO could have obtained by directly holding the intermediary's asset portfolio and financing it with the largest possible amount

of risk-free debt

$$\begin{aligned}
&\tfrac{\sum_f p_{f,1}(B_1)[q^I_{f,1}(B_1)-Q^I_0\pi(f)]}{1+R_d}+\tfrac{\sum_f f q^I_{f,1}(B_1)}{(1+R_d)^3}\\
&+Pr(G_1)\tfrac{\frac{1}{(1+R_d)^2}Q^I_0-\sum_f\left[p_{f,1}(B_1)[q^I_{f,1}(B_1)-Q^I_0\pi(f)]+\frac{f}{(1+R_d)^2}q^I_{f,1}(B_1)\right]}{1+R_e}\\
&+Pr(B_1)Pr(G_2)[\tfrac{\frac{1}{(1+R_d)}\sum_f(1-f)q^I_{f,1}(B_1)}{(1+R_e)^2}] \qquad . \qquad \text{(A.32)}
\end{aligned}$$

As a result, the intermediary is unable to pay a strictly higher price than the CLO to buy loans at time 0, and the intermediary is unable to generate a positive profit.

Next, suppose that the CLO sells the security at time B_1 to the outside financier. We make one crucial assumption about the security the intermediary issues:

Assumption 1. *If the security issued by intermediary I is sold at time t to outside financiers at time 1, it experiences the same fire-sale discount $D(s_{f_l,2})$ as a low quality loan sold to outside financiers.*

The security therefore has a price

$$\begin{aligned}
p^I_{0,FS}(\{d^I_t\}) =&\tfrac{1}{1+R_d}\left[d^I_1(B_1)+\tfrac{(1-D(s_{f_l,2}))[Pr(B_2)d^I_2(B_2)+Pr(G_2)d^I_2(G_2)]}{(1+R_a)}\right]\\
&+\tfrac{Pr(G_1)}{1+R_e}\left[d^I_1(G_1)-d^I_1(B_1)+\tfrac{(1-D(s_{f_l,2}))[Pr(B_2)d^I_2(B_2)+Pr(G_2)d^I_2(G_2)]}{(1+R_a)}\right]. \qquad \text{(A.33)}
\end{aligned}$$

The sum of this price plus the present value of the intermediary's dividends is

$$\begin{aligned}
&\tfrac{1}{1+R_d}\left[d^I_1(B_1)+\tfrac{(1-D(s_{f_l,2}))[Pr(B_2)d^I_2(B_2)+Pr(G_2)d^I_2(G_2)]}{(1+R_a)}\right]\\
&+\tfrac{Pr(G_1)}{1+R_e}\left[d^I_1(G_1)-d^I_1(B_1)+\tfrac{(1-D(s_{f_l,2}))[Pr(B_2)d^I_2(B_2)+Pr(G_2)d^I_2(G_2)]}{(1+R_a)}\right]\\
&+Pr(B_1)\tfrac{\sum_f p_{f,1}(B_1)[Q^I_0\pi(f)-q^I_{f,1}(B_1)]-d^I_1(B_1)}{1+R_e}+Pr(G_1)[\tfrac{\frac{1}{(1+R_d)^2}Q^I_0-d^I_1(G_1)}{1+R_e}]\\
&+Pr(B_1)\left[Pr(B_2)\tfrac{\sum_f\frac{f}{(1+R_d)}q^I_{f,1}(B_1)-d^I_2(B_2)}{(1+R_e)^2}+Pr(G_2)\left[\tfrac{\frac{1}{1+R_d}\sum_f q^I_{f,1}(B_1)-d^I_2(G_2)}{(1+R_e)^2}\right]\right]. \qquad \text{(A.34)}
\end{aligned}$$

The CLO's willingness to pay for any cash flow is never less than that of an equity in-

vestor, so this sum is made weakly larger by increasing each payout to its maximum feasible value $d_1^I(B_1) = \sum_f p_{f,1}(B_1)[Q_0^I\pi(f) - q_{f,1}^I(B_1)], d_2^I(B_2) = \sum_f \frac{f}{(1+R_d)} q_{f,1}^I(B_1), d_2^I(G_2) = \sum_f \frac{1}{(1+R_d)} q_{f,1}^I(B_1)$. Expression A.34 is therefore not greater than

$$\frac{1}{1+R_d}\left[\sum_f p_{f,1}(B_1)[Q_0^I\pi(f) - q_{f,1}^I(B_1)] + \frac{(1-D(s_{f_l,2}))[[Pr(B_2)\sum_f \frac{f}{(1+R_d)} q_{f,1}^I(B_1) + Pr(G_2)\frac{1}{(1+R_d)}\sum_f q_{f,1}^I(B_1)]}{(1+R_a)}\right]$$
$$+ \frac{Pr(G_1)}{1+R_e}\left[\frac{1}{(1+R_d)^2} Q_0^I - [\sum_f p_{f,1}(B_1)[Q_0^I\pi(f) - q_{f,1}^I(B_1)]\right.$$
$$\left. + \frac{(1-D(s_{f_l,2}))[Pr(B_2)\sum_f \frac{f}{(1+R_d)} q_{f,1}^I(B_1) + Pr(G_2)\frac{1}{(1+R_d)}\sum_f q_{f,1}^I(B_1)]}{(1+R_a)}\right]. \tag{A.35}$$

Since $p_{f,1}(B_1) \geq \frac{(1-D(s_{f_l,2})[fPr(B_2)+Pr(G_2)]}{(1+R_a)(1+R_d)}$, this is not greater than

$$\frac{1}{1+R_d}\sum_f p_{f,1}(B_1)Q_0^I\pi(f) + \frac{Pr(G_1)}{1+R_e}[\frac{1}{(1+R_d)^2}Q_0^I - \sum_f p_{f,1}(B_1)Q_0^I\pi(f)]. \tag{A.36}$$

This is precisely the value the CLO would obtain by buying a quantity of loans Q_0^I itself and selling it in state B_1. Because the CLO is willing to pay this amount to purchase loans at time 0, the intermediary is unable to make a positive profit by buying loans itself. This proves that in the equilibrium with both CLOs and banks, no third structure of intermediary can enter and make a strictly positive profit.

A.5 Demand for CLO Debt from Insurance Companies

This appendix explains why insurance companies, not only banks, are natural investors in the debt of CLOs. We model an insurance company as a financial intermediary who directly meets the demand of households for holding long-maturity risk-free assets. This assumption stands in for the fact that life-insurers, who play the largest role of all insurers in the fixed income market, are largely financed by policies that pay off based on the future mortality of their customers. Because mortality risk is largely idiosyncratic, paying off a diversified

pool of life insurance policies is quite close to making payments on a long-maturity risk-free bond.

We therefore assume that an insurance company issues risk-free bonds that pay out at $t = 3$ at a rate R_{In} as well as equity that bears all risk in its asset portfolio with the same required return R_e as other intermediaries. In addition, we assume that at any time t, the portfolio held by an insurance company must be sufficient to repay its outstanding debt if held to maturity. This reflects the fact that insurers' solvency regulations tend to statically compare current asset and liabilities. Insurers do not have a system of financial covenants that incentivize portfolio rebalancing similar to CLOs by restricting dividend payouts. An insurer faces the following problem

$$\max_{Q_0^{In}, d_0^{In}, q_{f,t}^{In}} \left\{ -p_0 Q_0^{In} + d_0^{In} + \mathrm{E}\left[\sum_{t=1}^{3} \tfrac{\delta_t^{In}}{(1+R_e)^t} \right] \right\}. \tag{A.37}$$

subject to the quality evolution $Q_0^{In}\pi(f) = q_{f,0}^{In}$ at time 1, the budget constraints

$$\overbrace{\delta_t^{In}}^{\text{Dividend payout}} = \overbrace{\sum_f p_{f,t}\left(q_{f,t-1}^{In} - q_{f,t}^{In}\right)}^{\text{Net asset sales}} \geq 0, \qquad t = 1, 2, \tag{A.38}$$

$$\overbrace{\delta_3^{In}}^{\text{Dividend payout}} = \overbrace{\sum_f \delta_{f,3}\, q_{f,2}^{In}}^{\text{Final asset payoff}} - \overbrace{(1+R_{In})^3 d_0^{In}}^{\text{Debt repayment}} \geq 0, \qquad t = 3. \tag{A.39}$$

and the "static" solvency constraint

$$\overbrace{\sum_f \delta_{f,3}\, q_{f,1}^{In}}^{\text{Asset payoff}} - \overbrace{(1+R_{In})^3 d_0^{In}}^{\text{Debt repayment}} \geq 0. \tag{A.40}$$

By arguments similar to those for the CLO and bank in the main text, and assuming that one-period risk-free assets can still be financed at the rate R_d, the insurance company's

willingness to pay for an asset it sells at date 1 is

$$p_0^{In,FS} = \frac{\sum_f \pi(f) f}{(1+R_{In})^3} + Pr(B_1)\frac{\pi(f_l)p_{f_l,1} - \frac{f_l}{(1+R_d)^2}}{1+R_e} + Pr(G_1)\frac{1-\sum_f f\pi(f)}{(1+R_e)(1+R_d)^2} \tag{A.41}$$

and that it holds to maturity is

$$p_0^{Im,\text{HTM}} = \frac{\sum_f f\pi(f)}{(1+R_{In})^3} + \frac{\Pr(G_1)}{1+R_e}\left[\frac{1-\sum_f f\pi(f)}{(1+R_d)^2}\right] + \frac{\Pr(G_2)\Pr(B_1)}{(1+R_e)^2}\left[\frac{1-\sum_f f\pi(f)}{1+R_d}\right]. \tag{A.42}$$

In an economy where $R_{In} = R_d$, so that both banks and insurers jointly buy the debt of CLOs, the FS willingness to pay is strictly below that of a CLO, while the HTM willingness to pay is identical to that of a CLO. It follows that in an economy where insurers and banks are willing to fund CLOs at the same risk-free cost of capital, there is an equilibrium where all risky loans are held by CLOs.

A.6 Robustness of Results to Partial Run Constraint

In this appendix, we show that our main results are robust to a range of variations in the bank's no-run constraint. We consider two possibilities: either that a fraction $\lambda < 1$ of depositors are attentive enough to withdraw in a run or that some fraction $\lambda < 1$ of deposits are insured even in the presence of a run. However, such deposit insurance is combined with a regulatory constraint that the bank still has enough assets to repay its deposits in the long run. In such a setting, only a fraction λ of depositors will withdraw in a possible run. As a result, a bank's "no-run" constraint now requires at time t that a bank be able to repay a fraction λ of its depositors at time t+1 and the remaining $1-\lambda$ at time t+2. At time $t = 1$, this constraint becomes

$$d_1(1+R_d) \leq \sum_f q_{f,1}^B f \frac{[1-D(s_{f,2})]\lambda + (1-\lambda)}{(1+R_d)}. \tag{A.43}$$

This constraint is equivalent to the bank's solvency constraint in the main text, but at a strictly smaller value of $D_f^{small}(B_1)$, so that $1-D_f^{small}(B_1) = [1-D(s_{f,2})]\lambda+(1-\lambda)$. Because our results about the structure of bank and CLO balance sheets hold for any $D_f^{small}(B_1)$ that is positive for low-quality loans, this bank still chooses to only hold long-maturity risk-free CLO debt as well. If, instead, we had that $\lambda = 0$, the bank would have the same willingness to pay for loans as the CLO and could lend to firms directly. In addition, because our results show that the difference between a bank and CLO's willingness to pay for a loan is decreasing in $D(s_{f_l,2})$, it immediately follows that this difference also decreases in λ.

B Numerical Exercise Appendix

Our calibration targets for loan returns come from the time series of the Morningstar LSTA Leveraged Loans Index spanning 2000 to 2024. We calculate the unconditional probability of a crisis as $\frac{1}{12}$, considering the Global Financial Crisis (GFC) and the Covid crisis as the only two crises over the 24-year sample. We compute returns as

$$Ret_t = \frac{\text{Close Price}_t}{\text{Close Price}_{t-1}} - 1.$$

The model matches the annualized average return on the index, 5.06%, with

$$\frac{1-\Pr(B)\Pr(B)+\Pr(B)\Pr(B)\sum f\pi(f)}{p_0} = (1+0.0506)^3.$$

We compute the change in price between $2008-06-30$ (GFC peak) and $2008-12-31$ (GFC through) and between $2020-01-31$ (Covid crisis peak) and $2020-03-31$ (Covid through) and average the two. The resulting target is 0.79. In the same way, we compute the change in price $2008-12-31$ (GFC through) and $2009-12-31$ (GFC recovery) and between $2020-03-31$ (Covid through) and $2021-02-28$ (Covid recovery) and average

the two. The resulting target is 1.4. The model counterparts are:

$$\frac{\sum p_{f,1}(B)\pi(f)}{p_0} = 0.79,$$
$$\frac{\frac{1}{1+R_d}(\Pr(G)+\sum f\pi(f)\Pr(B))}{\sum p_{f,1}(B)\pi(f)} = 1.4.$$

Fire Sale Cost. We start from the expression for the fire sale price

$$p_{f,1}^{FS}(s_{f,2}) = (1 - D(s_{f,2}))\, p_{f,1}^{FS}(0),$$

where $p_{f,1}^{FS}(0) = \frac{f+\Pr(G)(1-f)}{(1+R_a)(1+R_d)}$. Taking the derivative of the price (change) with respect to $s_{f,2}$ we get

$$p_{f,1}^{'FS}(s_{f,2}) = -D'(s_{f,2})p_{f,1}^{FS}(0).$$

Dividing both sides by $p_{f,1}^{FS}$ we get the percent change in price (given that $s_{f,2} \in [0,1]$

$$\frac{p_{f,1}^{'FS}(s_{f,2})}{p_{f,1}^{FS}(s_{f,2})} = -D'(s_{f,2})\frac{p_{f,1}^{FS}(0)}{p_{f,1}^{FS}(s_{f,2})} = \frac{-D'(s_{f,2})}{1-D(s_{f,2})}.$$

Notice that the left-hand side represents exactly $d\log p_{f,1}^{FS}(s_{f,2})/ds_{f,2}$ and so maps into the definition of the (negative) price impact per unit of quantity sold (percentage change) as provided in Elkamhi and Nozawa (2022) and equal to 2.34%. We time this number by the share of loans held by CLO which is roughly 40%. Hence a function for $(1 - D(s_{f,2}))$ that satisfies this equation is $\exp(-2.34 * 0.4 s_{f,2})$. Hence we can impute $\kappa = 2.34 * 0.4$.

C Quantitative Model Appendix

C.1 Calibration

We assume that the aggregate state Z_t^i and the idiosyncratic state z_t^i follow the AR(1) processes

$$\overbrace{Z_t}^{\text{Aggregate state}} = \rho^{\text{agg}} Z_{t-1} + (1-\rho^{\text{agg}})\,\mu^{\text{agg}} + \sigma^{\text{agg}}\,\varepsilon_t^{\text{agg}} + \zeta\,\xi_t, \tag{C.44}$$

$$\overbrace{z_t^i}^{\text{Firm } i\text{'s state}} = \rho^{\text{idio}}\, z_{t-1}^i + (1-\rho^{\text{idio}})\,\mu^{\text{idio}} + \sigma^{\text{idio}}\,\varepsilon_t^i. \tag{C.45}$$

Here, $\varepsilon_t^{\text{agg}}, \varepsilon_t^i$ are each distributed $\mathcal{N}(0,1)$ and are i.i.d. across all firms i and times t. In addition, ξ_t are i.i.d. Bernoulli random variables that are independent of all ε shocks that can cause a "disaster" where output drops significantly. We discretize Z_t and z_t^i into finite-state Markov chains using the method of Rouwenhorst (1995).

Table 5: Model Parameters

Parameters	**Definition**	**Value**	**Source**
Return on CLO equity	R_e	0.0988	Cordell et al. (2021)
Interest on CLO AAA debt tranche	r_{CLO}	0.02	Cordell et al. (2021)
Interest on Leveraged Loan	r_l	0.045	Elkamhi et al. (2024)
Covenant tightness	$\lambda_{IC}, \lambda_{OC}$	.2, .24	Semeris Data
Probability of crisis	$\Pr(\xi_t = 1)$	0.083	LSTA US Leveraged Loan (2000-2024)
Magnitide of crisis	ζ	-.5	
Normal shock variances	$\sigma^{\text{idio}}, \sigma^{\text{agg}}$	.3, .2	
Means	$\mu^{\text{agg}}, \mu^{\text{idio}}$	0,-1.4	
Autocorrelations	$\rho^{\text{agg}}, \rho^{\text{idio}}$	.5,.9	
Recovery of Defaulted Loan	χ	.8725	Loan Recovery=.6 (Moody's)
Loan Maturity	δ_L	.8935	Duration=6.6 ($\approx$ 10 year loan)

Parameterization of the quantitative model.

Table 5 shows the parameters of our calibrated model. The only parameters which do

not directly map to external estimates are those driving the time-series process of leveraged loan cash flows. Here, our calibration is chosen to yield a realistic 4% overall average default rate, which grows significantly in states when Z is lowest.

In addition, we calibrate the loan prices $p_t(z_t^i)$ to have significant time-series and cross-sections variation in expected returns. The stochastic discount factor at time t for cash-flows at time $t+1$ is of the form $SDF_{t,t+1} = K_0(Z_t)exp(K_1(Z_t) * Z_{t+1})$. The parameter K_0's variation across states of the world controls time-series variation in expected returns, while the magnitude of $K_1(Z_t)$ controls the degree of cross-sectional heterogeneity in expected returns at a given point in time. We choose $K_1(Z_t)$ in each state so investors are indifferent between a credit default swap that covers default losses on the highest idiosyncratic quality loan[2] at time $t+1$ and a risk-free payoff of one third the expected payoff, in the middle of the range of credit risk premia in Berndt et al. (2018) for investment grade credit. In addition, we set $K_0(Z_t)$ so that the risk-free rate implicit in leveraged loan returns is $\max(1.0437, 1.0437 - .1Z_t)$. This matches the return on assets R_a from our theoretical model in good states of the world and yields significantly higher returns in crises when Z_t is negative.

[2]Our discretization has 5 idiosyncratic loan qualities and 13 values of the aggregate state Z.