Financial Market Structure and the Supply of Safe Assets: An Analysis of the Leveraged Loan Market

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Abstract

This paper develops an equilibrium model in which collateralized loan obligations (CLOs) create safe securities to finance risky lending and replace deteriorated loans through secondary market trading. Consistent with empirical evidence, the resulting market structure consists of two groups of financial intermediaries: CLOs and non-securitized lenders. Trading loans with non-securitized lenders allows CLOs to issue larger safe tranches ex ante but generates price pressure in downturns. Since intermediaries do not internalize their effect on loan prices, there is excessive entry into operating CLOs, and the market underproduces safe assets. A recent regulation that reduced CLO entry could exacerbate the inefficiency.

JEL classifications: G11, G23, G28

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Introduction

Safe assets, namely debt instruments with very low probabilities of default, are priced at a premium for their convenience benefits (Krishnamurthy and Vissing-Jorgensen, 2012; Nagel, 2016; Van Binsbergen, Diamond, and Grotteria, 2022). The existence of this premium incentivizes the private sector to repackage risky loans into securities, with the intention of creating safe senior tranches (Gorton and Metrick, 2013; Gorton, 2017). Securitization started with mortgage loans in the 1970s and gradually extended to other asset classes. In the late 1990s, collateralized loan obligations (CLOs) were introduced to create AAA-rated securities backed by speculative-grade corporate loans ("leveraged loans"). Since 2008, CLOs have financed more than $2 trillion of leveraged loans.

The key innovation of CLOs is that the underlying loans are actively managed, which allows for a larger safe senior tranche given the same initial collateral. With a dynamic portfolio, the manager can maintain collateral quality by selling loans whose quality deteriorates and buying less risky loans. These trades prevent the portfolio's subsequent cash flows from being too low, which protects the senior tranche *ex post* and provides greater safe debt capacity *ex ante*.

The leveraged loan market meets two necessary conditions for the use of dynamic trading to increase safe debt capacity. First, CLO managers can credibly commit to their promised trades[1], and second, there are sufficient counterparties who are willing and able to trade with CLOs. Unlike other private debt, the vast majority of leveraged loans are individually rated by third parties, and long-term contracts based on the ratings allow managers to commit to replacing deteriorated loans. The market also has a unique market structure whereby two distinct groups of intermediaries coexist. In addition to the CLOs, non-securitized lenders, including mutual funds and hedge funds, are also active in the market and serve as natural

[1] Otherwise, the risk-shifting incentives of a leveraged intermediary may lead to even less safe debt capacity than allowed with static collateral.

secondary market counterparties.

This paper provides a theoretical analysis of safe asset production by CLOs. Specifically, I develop an equilibrium model of securitized lending to study the supply of safe assets and the dynamic trading of the underlying loans. The model's main insight is that when managers can credibly promise to maintain collateral quality, intermediaries with two distinct types of liabilities endogenously coexist, and the market produces a greater quantity of safe assets than in static securitization (Proposition 1). I then show that the competitive equilibrium may not be socially optimal (Proposition 2) and that a recently implemented policy can exacerbate the inefficiency (Proposition 3).

I illustrate these results within the context of a three-period model. Investors in the model get convenience benefits from safe assets, which are created when intermediaries raise external financing for their risky lending. An intermediary's safe debt capacity is determined by its loan portfolio's worst possible payoff in the final period, and loans may deteriorate after origination because of aggregate shocks. Deteriorated loans are riskier and might pay off poorly, but which loans will deteriorate is unknown ex ante. After deterioration, intermediaries can trade loans among themselves in a secondary market.

My model rationalizes the observed market structure as an equilibrium outcome. In particular, two groups of intermediaries emerge and coexist. The first group, which resemble CLOs, maximize safe debt capacity by promising to maintain collateral quality. The second group, which resemble non-securitized lenders, choose not to issue any safe debt. In bad times, the first group sell deteriorated loans and buy less risky loans. These trades cause the price of bad loans to decrease relative to the price of good loans, making it profitable to trade with the CLOs. Attracted by the profit opportunities, the second group give up issuing safe debt ex ante and provide collateral in the secondary market.

I demonstrate that secondary market trades can increase the supply of safe assets through specialization. Intuitively, the CLOs' promise to replace deteriorated loans facilitates a transfer of safe debt capacity between the two groups. This transfer can benefit all intermediaries when they are heterogeneous in securitization technology. Non-securitized lenders, who lack superior technology to securitize loans, lend more than in static securitization and profit from the secondary market. Meanwhile, the increased lending provides more collateral for CLOs, who face lower costs of securitization, to produce a greater supply of safe assets.

However, the equilibrium is not necessarily socially efficient. The source of inefficiency is a pecuniary externality: intermediaries ignore the equilibrium effects of their lending and financing choices on loan prices. On the asset side, there is underinvestment because the private profits of lending are lower than the social value of collateral. On the liability side, issuing safe debt can be privately optimal but socially wasteful because doing so reduces the collateral available to others. These two forces jointly depress the marginal rate of collateral substitution, tightening CLOs' binding collateral constraints. As a result, there is excessive entry into operating CLOs, and the market underproduces safe assets relative to a constrained planner's allocation.

This constrained inefficiency creates the rationale for regulatory intervention, but the market structure presents unique policy challenges. In particular, traditional policies targeting either side of intermediary balance sheets cannot move the market towards constrained efficiency and may exacerbate the welfare loss through equilibrium effects. For example, given the equilibrium's welfare properties, one might conjecture that a policy that reduces entry into operating CLOs could improve welfare. By introducing an entry cost into the model, I show that such a policy exacerbates the underproduction of safe assets. This is because a reduction in CLO entry makes providing collateral in the secondary market less profitable. Anticipating lower profits, non-securitized lenders decrease their lending, which worsens the shortage of aggregate collateral.

Through the lens of the model, I shed light on a controversial regulation. This regulation, called Credit Risk Retention Rule, requires asset managers to contribute 5% of capital to the

CLOs they operate. Because the rule imposes substantial operational and capital costs on issuing safe securities, its introduction in 2014 has led to a decrease in the number of new CLOs and resistance from practitioners. After winning a lawsuit against regulators in 2018, CLO managers were exempted from the rule, but there is still an ongoing debate over this exemption. My analysis explains, from an equilibrium perspective, why this policy may cause unintended consequences that regulators should take into consideration.

The implications of my model are broadly consistent with empirical observations. Fabozzi et al. (2021) find that CLOs' purchases and sales of loans are associated with less portfolio deterioration. Tracking the dynamics of loan ownership, Giannetti and Meisenzahl (2021) show that mutual funds and hedge funds buy deteriorated loans sold by CLOs. Simultaneous trades initiated by many CLOs exert pressure on loan prices (Elkamhi and Nozawa, 2022), creating profit opportunities for the counterparties. In addition to existing evidence, I document that, triggered by binding collateral constraints, CLOs' portfolio substitution in the COVID-19 crisis substantially improves their collateral quality.

This paper contributes to several strands of literature. First, my analysis of nonbanks offers a new perspective on financial intermediation. Seminal work by Diamond and Dybvig (1983) and Gorton and Pennacchi (1990) show that intermediaries facilitate efficient allocation by creating safe and liquid claims. Subsequent research further develops the insight that safety creation drives intermediary asset choices.[2] DeAngelo and Stulz (2015) analyze bank capital structure and risk management when safe debt commands a premium. Dang et al. (2017) argue that by discouraging information production, holding opaque assets helps banks make their deposits safe. Diamond (2020) models safe asset production in an endowment economy in which intermediary balance sheets are jointly determined with the liabilities of non-financial firms. In the existing literature, there is no role for dynamic asset portfolios in

[2]Several papers argue that an excessive production of private safe assets can lead to financial fragility through fire sales (Stein, 2012; Greenwood, Hanson, and Stein, 2015) or neglected risks (Gennaioli, Shleifer, and Vishny, 2012, 2013).

the production of safe liabilities. My innovation is to analyze how secondary market trading allows intermediaries to create safe assets beyond static pooling and tranching. The idea of collateral reallocation is shared by Holmström and Tirole (1998, 2001), where trading mitigates the impact of liquidity shocks on firms' real investment.

My normative analysis builds on the theoretical literature on pecuniary externalities associated with price-dependent borrowing constraints, which Dávila and Korinek (2018) classify as "collateral externalities". In Gromb and Vayanos (2002), competitive arbitrageurs trading in segmented markets face collateral constraints, through which asset prices prevent efficient risk taking. Stein (2012) analyzes banks that issue short-term safe debt that may be repaid by liquidating loans. He shows that banks overproduce safe assets as they fail to internalize that lower loan prices cause underinvestment by nonbanks. Neuhann (2019) focuses on loan buyers who ignore that higher prices relax bank collateral constraints and reduce the incentives to screen loans. My model differs in that intermediaries with identical lending technology trade loans among themselves after choosing different liabilities. As the prices and constraints depend on the balance sheets of all counterparties, the equilibrium features safe asset underproduction and presents new policy implications.

This paper also contributes to a fast-growing body of empirical research on leveraged loans and CLOs. Existing studies on CLO portfolios generally take the contracts as given and document that managers strategically trade loans that are marked-to-market (Elkamhi and Nozawa, 2022; Kundu, 2021) or have higher prices (Loumioti and Vasvari, 2019; Nicolai, 2020). Research focused on the liability side has studied the realized returns (Cordell, Roberts, and Schwert, 2021), secondary market transactions (Foley-Fisher, Gorton, and Verani, 2020), and credit ratings (Griffin and Nickerson, 2020) of CLO securities. However, there is limited understanding on how intermediary liabilities are shaped by the CLO contracts and the resulting loan trades. This paper fills the gap by providing an equilibrium framework that explains the dynamics of CLO balance sheets and the structure of the leveraged loan market.

The remainder of this paper is organized as follows. Section 1 presents institutional background and empirical facts. Section 2 introduces the model, and Section 3 characterizes the equilibrium. Section 4 analyzes the equilibrium's welfare properties and the effects of policy interventions, and Section 5 concludes.

1 Institutional Background and Empirical Facts

Leveraged loans are private debt extended to corporations that have a high existing leverage.[3] These loans are originated through syndication deals, where underwriters organize select groups of lenders to privately contract with the borrowers. Following the Federal Reserve Board (2021), this paper restricts attention to "institutional leveraged loans", which are term loans and mostly held by nonbanks. CLOs are the largest group of nonbank intermediaries that hold leveraged loans. As Figure 1 shows, US leveraged loans quickly grew from \$130 billion to \$1.2 trillion between 2001 and 2020, and CLOs consistently held roughly half of these loans. The vast majority of CLOs are "open-market CLOs", which are operated by asset managers that are independent from the underwriter banks.

Unlike other asset-backed securities (ABS) that are backed by static collateral, CLOs allow their managers to actively manage the underlying loans during a reinvestment period. A CLO lasts around 10 years, and the length of the reinvestment period is usually 4 to 5 years, with optional extensions. After this, the CLO enters its amortization period and repays debt principal over time.[4] The manager's compensation consists of fixed fees, which are based on tranche size, and incentive fees, which are based on the equity tranche's performance.

Safe Asset Production. Since no asset is literally risk free, the definitions of safe assets

[3] S&P Global Market Intelligence defines a loan as leveraged if it is rated below Baa3/BBB-, or if it is secured and has a spread of at least 125 basis points.

[4] During the amortization period, CLO managers can only buy loans using the cash generated by existing loans' prepayments. See Fitch's report for more details: Reinvestment in Amortization Period of U.S. CLOs.

are diverse and sometimes vague. Existing definitions often involve the convenience services provided by low-risk debt instruments. In the context of this paper, such services are reflected in that highly-rated CLO securities help regulated financial institutions satisfy risk-based capital requirements (Benmelech and Dlugosz, 2009). While leveraged loans have speculative-grade ratings, CLOs' senior debt tranches (about 65% of liabilities) are rated AAA and have never defaulted in history. The safety of senior tranches relies on several factors. First, the underlying portfolios are diversified, typically consisting of 100–300 loan shares. Second, the default recovery rates of leveraged loans have been moderately high.[5] Third, CLO contracts include covenants that protect debtholders, which I will introduce shortly.

Non-Securitized Lenders. In addition to CLOs, other nonbank intermediaries also hold a significant fraction of leveraged loans. These intermediaries, including mutual funds and hedge funds, do not collateralize their loan holdings to issue any safe securities. Since there is no regulatory entry barrier, asset managers participating in the leveraged loan market should be able to choose which type(s) of intermediaries to operate. Consistent with this conjecture, Figure 2 shows that managers selectively operate CLOs and/or mutual funds. For example, CVC Credit Partners only offers CLOs, whereas Fidelity Investments predominantly manages leveraged loan mutual funds. Such choices lead to a coexistence of two distinct groups of intermediaries with different liabilities.

Covenants and Collateral Constraints. The large size of leveraged loans, which ranges between hundreds of millions and billions of dollars, creates economies of scale in information production. As most of the loans are individually rated by third parties, CLO managers can commit to long-term contracts enforced based on the ratings and credibly promise to deteriorated loans. This commitment is implemented with regular (e.g., monthly) collateral tests that are linked to the manager's compensation. The most important test is the over-collateralization (OC) test, which calculates a ratio of quality-adjusted loan holdings to the

[5] Corporate loans are senior to bonds and usually explicitly secured by collateral. See S&P report for more details on recovery rates: LossStats.

size of the debt tranche.[6] When the OC test fails, the covenants require the manager to either trade loans or accelerate debt repayment to raise the ratio above a predetermined threshold.

Dynamics of CLO Balance Sheets. Collateral constraints imposed by the contracts play a crucial role in governing the dynamics of the CLO balance sheet. In Section IA.2 of the Internet Appendix, I provide detailed evidence for the following facts. First, the collateral constraints are persistently binding, which implies that CLO managers fully use their safe debt capacity. Second, in response to systematic loan deterioration caused by the COVID-19 crisis, CLOs substitute collateral by trading in the secondary market. Third, collateral substitution offsets a major fraction of loan deterioration, thus improving CLOs' portfolio quality relative to counterfactual portfolios.[7] Finally, these trades appear to exert asymmetric price pressure on loans of different quality.

2 An Equilibrium Model of Securitized Lending

This section presents an equilibrium model of securitized lending in which asset managers can credibly promise to maintain collateral quality through secondary market trading. The setup focuses on long-term contracts under full commitment and relegates the analysis of maturity choice and contractual frictions to Section IA.3 of the Internet Appendix. All proofs and derivations are in the Appendix.

2.1 Environment

The economy has three time periods $t \in \{0, 1, 2\}$ and two types of agents: investors and asset managers.

[6] Other collateral tests include the interest coverage (IC) test and interest diversion (ID) test, which also require the manager to hold enough collateral given their debt outstanding.

[7] Similar effects were observed during the 2008–2009 financial crisis (Standard & Poor's, 2016), suggesting that the contract design consistently protects senior tranches in bad times.

Investors. There is a unit mass of investors who receive an endowment e of perishable consumption goods in the beginning of period $t = 0$ and maximize additively separable utility

$$U = \mathbb{E}_0\left[\sum_{t=0}^{2} C_t\right] + \gamma A, \tag{1}$$

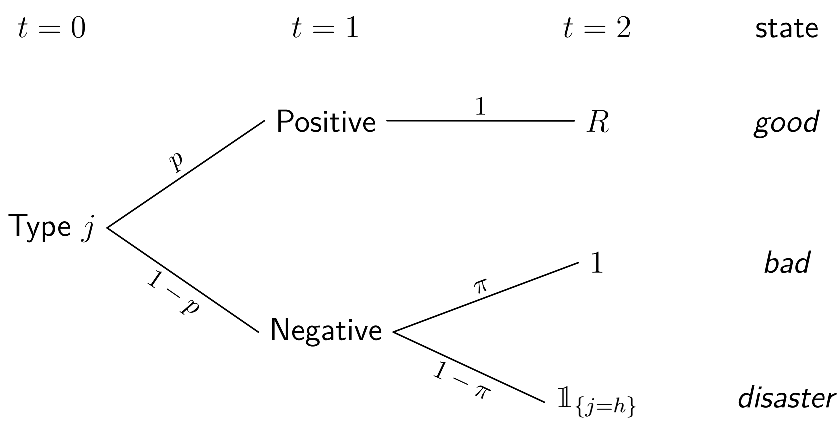
where C_t is consumption in period t, and A is the period-0 holding of riskless financial claims. From every unit of these claims, investors derive a non-pecuniary benefit γ because of the convenience services provided by safe assets.

Intermediaries. There is a continuum of asset managers uniformly populated on $\mathcal{I} = [0, 1]$. Their preference is the same as (1), except for that they do not benefit from holding safe assets. Each manager, indexed by $i \in \mathcal{I}$, has zero endowment and operates an intermediary that lends at $t = 0$ to generate a risky payoff at $t = 2$. Intermediaries can finance their lending by issuing any safe and risky financial claims. In particular, a claim is called *safe debt* if it is backed by loans whose payoff is enough for repayment with certainty. There exists a securitization technology that allows managers to commit to portfolio choices at $t = 1$ and thereby credibly issue safe debt. Issuing safe debt incurs an exogenous variable cost $\xi_i \geq 0$, which captures a manager's ability to adopt the technology.

A key friction in this economy is that financial markets are incomplete: agents cannot create or trade claims contingent on future states. For this reason, in the absence of safe debt issued by intermediaries, the supply of safe assets is zero. Investors take the prices of claims as given when making investment and consumption decisions. I assume e to be sufficiently large, so the nonnegativity constraint on investor consumption is never binding.

Investment Technology. Investors cannot lend directly. Managers have identical and independent access to two types of scalable investment projects $j \in \{h, l\}$. Every unit of capital in projects generates a gross payoff R_j^ω that depends on state $\omega \in \Omega = \{g, b, d\}$ at $t = 2$. In period $t = 1$, a piece of public news s arrives, which can be either positive ("+") or negative ("−") with probabilities p and $1 - p$, respectively. If s is positive, state g

(“good”) will realize with certainty, and both types of projects will pay $R^g_j = R > 1$ units of consumption goods. If s is negative, $t = 2$ state remains uncertain. With probability $\pi \in (0,1)$, state b (“bad”) realizes, and the two types both pay $R^b_j = 1$. With probability $1-\pi$, state d (“disaster”) realizes. Whereas type h still pays $R^d_h = 1$ in this state, type l pays $R^d_l = 0$. The existence of a strictly positive worst possible payoff R^d_h makes issuing long-term safe debt possible.[8]



An intermediary can lend $c(x)$ units of consumption goods to projects and convert them into x units of capital, where c is twice differentiable and satisfies $c(0) = 0$, $c'(\cdot) > 0$, and $c''(\cdot) < 0$. To simplify the analysis, I assume that project payoffs are fully pledgeable, and that managers enjoy full bargaining power. By lending to projects, the intermediary originates loans.[9] Depending on project types, I refer to the loans as h (high-quality, or “good”) and l (low-quality, or “bad”) loans, respectively. After negative news, loan quality deteriorates, and l loans become inferior to h loans.

Intermediary portfolios consist exclusively of risky loans. This is because consumption goods are nonstorable, cross-holdings of claims are unprofitable, and state-contingent contracts

[8] The payoff distribution is stronger than necessary but makes the model transparent. Subsection IA.3.1 of the Internet Appendix considers a setting with generalized conditional payoff distributions.

[9] In practice, underwriters originate leveraged loans and sell them to nonbanks. Since nonbanks typically pre-commit to buying loans from banks (Taylor and Sansone, 2006), and lead arrangers’ loan shares drop to negligible levels shortly after syndication (Lee et al., 2019), my model abstracts from the underwriting process and refer to the nonbank lending activity as “origination”.

(e.g., derivatives) between managers are unenforceable.

Financial Markets. Primary market events in period $t = 0$ occur in the following order. Each intermediary $i \in \mathcal{I}$ originates x_i units of loans without knowing their types. Immediately after origination, a quality shock determines loan types exogenously. Specifically, $\tilde{x}_{i,l}$ units of loans become type l, and the remaining $\tilde{x}_{i,h} = x_i - \tilde{x}_{i,l}$ units become type h. Across intermediaries, $\tilde{x}_{i,l}$ is independently drawn from a common distribution with support $[0, \bar{x}_l]$ and mean $x_L \in (0, \bar{x}_l)$. The realization of the quality shock, $x_{i,l}$, is publicly observed, but which loans are low-quality is unknown in this period. To finance the investment cost $c(x_i)$, the intermediary then issues safe debt with face value $a_i \geq 0$ and external equity shares. Since only safe debt provides convenience services, here equity can be interpreted as any risky liability, such as junior debt.

In period $t = 1$, loan quality types become publicly observable, and intermediaries can trade loans in a Walrasian secondary market. Let loan prices after news s be $(q_l^s, q_h^s) \in \mathbb{R}_+^2$. By substituting loans, secondary market trading can generate a different worst possible portfolio payoff than that of a static portfolio. In period $t = 2$, project payoffs realize, and capital fully depreciates. Managers repay investors and collect residual portfolio payoffs. All goods are consumed, and the economy ends.

The Intermediary's Optimization Problem. Asset managers make sequential choices to maximize their own payoffs. I describe their optimization problem backwardly and only consider repayment in the final period. The option of repaying debt in period $t = 1$, as I show in Section IA.3 of the Internet Appendix, can be ignored without loss of generality under the setup in the current section.

After news s arrives in period $t = 1$, given the intermediary's balance sheet $(x_{i,h}, x_{i,l}, a_i)$, manager i chooses net trades $\Delta x_{i,h}^s, \Delta x_{i,l}^s$ of the two types of loans to maximize conditional expected payoff to equity

$$v(x_{i,h}, x_{i,l}, a_i; s) = \max_{\Delta x^s_{i,h}, \Delta x^s_{i,l}} \sum\nolimits_j (x_{i,j} + \Delta x^s_{i,j}) \mathbb{E}[R^\omega_j | s] - a_i. \tag{P1}$$

These trades are subject to a budget constraint

$$\sum\nolimits_j (x_{i,j} + \Delta x^s_{i,j}) q^s_j \leq \sum\nolimits_j x_{i,j} q^s_j, \tag{BC}$$

a maintenance collateral constraint

$$a_i \leq \sum\nolimits_j (x_{i,j} + \Delta x^s_{i,j}) \min_{\omega \in \Omega^s} R^\omega_j \tag{MCC}$$

where $\Omega^s = \{\omega \in \Omega : \Pr(\omega|s) > 0\}$, and short-sale constraints $\Delta x^s_{i,h} \geq -x_{i,h}, \Delta x^s_{i,l} \geq -x_{i,l}$. Constraint (BC) requires the intermediary's trades to be self-financed by its loan portfolio. Constraint (MCC) requires that after secondary market trades, safe debt investors will receive the face value with probability one. The latter constraint keeps the intermediary in the solvent region, hence equity payoff in (P1) is linear in portfolio payoff.

Managers rationally anticipate loan trades in period $t = 1$ when making lending and financing decisions in period $t = 0$. Because investors are price-taking, managers optimally price securities such that investors break even in expectation. This implies that by issuing one unit of safe debt, an intermediary effectively raises $1 + \gamma - \xi_i$, and the cost of external equity is $c(x_i) - (1 + \gamma - \xi_i)a_i$. Taking anticipated loan prices as given, the manager chooses investment x_i and safe debt a_i to maximize the expected payoff to internal equity

$$V_i = \max_{x_i, a_i \geq 0} \quad \mathbb{E}_0[v(x_{i,h}, x_{i,l}, a_i; s)] - \Big(c(x_i) - (1 + \gamma - \xi_i)a_i\Big), \tag{P0}$$

where $v(x_{i,h}, x_{i,l}, a_i; s)$ is the $t = 1$ maximum expected equity payoff as a function of choices x_i, a_i, and the realization of shock $\tilde{x}_{i,l}$. Importantly, the maximization is subject to an endogenous initial collateral constraint:

$$a_i \leq \Big(\sum\nolimits_j x_{i,j} q^s_j\Big) \max_j \min_{\omega \in \Omega^s} \frac{R^\omega_j}{q^s_j}, \ \ \forall s \tag{ICC}$$

which requires the portfolio's market value at $t = 1$ to be enough for the manager to satisfy constraint (MCC) through loan trades.

I impose two parametric assumptions. First, the convenience yield is large enough such that any manager can lower the cost of financing by issuing safe debt.

Assumption 1. *Investors' non-pecuniary benefit is greater than any manager's safe debt issuance cost:* $\gamma > \xi_i$ *for all* $i \in \mathcal{I}$.

Second, the quantity of low-quality loans in a portfolio, $\tilde{x}_{i,l}$, is bounded from above.

Assumption 2. *The marginal cost of real investment at scale* $\bar{x}_l$ *satisfies* $c'(\bar{x}_l) < pR + 1 - p$.

This inequality ensures that the sequential choices within period $t = 0$ can be equivalently formulated as a simultaneous decision problem.

2.2 Equilibrium Definition

Because of the collateral constraints, intermediaries' ex-ante lending and financing affect their ex-post trades, which in turn affect the balance sheet choices through loan prices. As such, the equilibrium features a feedback loop between primary and secondary markets.

Definition 1 (Competitive Equilibrium)**.** *An equilibrium consists of balance sheet choices* (x_i, a_i)*, secondary market trades* $(\Delta x^s_{i,h}, \Delta x^s_{i,l})$*, and secondary market loan prices* (q^s_h, q^s_l) *such that (i) given loan prices, balance sheet choices solve the manager's lending and financing problem (P0), (ii) given loan prices, secondary market trades solve the manager's trading problem (P1), and (iii) the secondary market clears, that is,*

$$\int_i \Delta x^s_{i,j} \, \mathrm{d}i = 0 \quad \text{for } j \in \{h, l\}, s \in \{+, -\}. \tag{2}$$

2.3 Discussion of Model Setup

My model builds on two main assumptions. First, investors get utility from safe assets, which is standard in the literature (e.g., Krishnamurthy and Vissing-Jorgensen, 2012; Stein, 2012; Diamond, 2020).[10] Because of this preference, safe debt can be priced at a premium, and an intermediary's capital structure is relevant to its value, breaking the Modigliani and Miller (1958) theorem. Empirically, CLO debt tranches are overpriced on a risk-adjusted basis relative to leveraged loans, which helps the equity tranches earn high returns (Cordell, Roberts, and Schwert, 2021). Second, financial investment exhibits decreasing returns to scale, so intermediaries face a scarcity of loans. This is consistent with the large number of CLOs and managers and the relatively small size of their loan portfolios.

The securitization technology that allows managers to commit to satisfying the collateral constraints is crucial for debt safety. In practice, CLOs only hold fairly standardized corporate loans, so that long-term contracts can effectively discipline the manager's portfolio choices. With simple collateral, CLOs are vastly different from pre-crisis collateralized debt obligations (CDOs), which held enormous complex derivatives such as credit default swaps (Cordell, Huang, and Williams, 2011). Consistent with these facts, intermediaries in the model cannot use state-contingent bilateral contracts.

Asset managers in the model may face different safe debt issuance costs. A lower cost can be interpreted as a technological advantage that arises from the manager's other businesses. For example, it is plausibly less costly for KKR than Fidelity to securitize loans and raise funding from global private markets. The issuance cost is assumed to be exogenous and proportional to safe debt for tractability, and qualitatively similar results can be derived under alternative assumptions.

[10] Since the magnitude of AAA CLOs is still small relative to other classes of safe assets (e.g, US Treasuries), for expositional simplicity I assume the marginal utility of holding safe assets to be constant.

3 Equilibrium Characterization

This section characterizes the equilibrium. First, I analyze individual managers' lending, financing, and trading choices for given secondary market loan prices. I then study intermediary balance sheets and loan prices that clear the secondary market. To provide a basic benchmark, I begin with a setting where collateral is restricted to be static.

3.1 Benchmark: Static Securitization

Consider the case where no secondary loan market exists, and intermediaries have to hold static portfolios. Let $c'^{-1}(\cdot)$ be the inverse function of the first-order derivative of c.

Lemma 1. *In the absence of a secondary loan market, every intermediary fully uses its safe debt capacity:* $x_i^{STA} = c'^{-1}(pR + 1 - p + \gamma - \xi_i)$ *and* $a_i^{STA} = x_i^{STA} - x_{i,l}$ *for all* $i \in \mathcal{I}$.

Without a secondary market, every intermediary pledges its static loan portfolio as collateral and fully uses safe debt capacity. The size of an intermediary's balance sheet decreases in the manager's cost of issuing safe debt. This market structure resembles traditional banking, where risky loans stay on bank balance sheets, and a bank's deposit productivity plays a key role in its value creation (Egan, Lewellen, and Sunderam, 2022).

3.2 Secondary Market Trades

The lending and financing choices at $t = 0$ depend on continuation value v. To derive v, in this subsection I analyze the manager's secondary market problem in period $t = 1$ for given balance sheet choices and loan prices.

Problem (P1) can be simplified as follows. First, the budget constraint (BC) binds because the objective is strictly increasing in net trades. Given constraint (ICC), this implies that after positive news, the maintenance collateral constraint (MCC) is slack for every manager, and secondary market trading is trivial with $q_h^+ = q_l^+ = R$. Therefore, I restrict attention to optimal trades in the negative-news stage at $t = 1$ and suppress the superscripts in net trades and loan prices hereafter. In this stage, since $a_i \geq 0$, (MCC) implies that $\Delta x_{i,h} \geq -x_{i,h}$ is slack. Omitting terms predetermined at $t = 1$, the problem is equivalent to

$$\max_{\Delta x_{i,l}} \quad \Delta x_{i,l}\left(\pi - \frac{q_l}{q_h}\right), \tag{P1a}$$

subject to constraints $\Delta x_{i,l}\frac{q_l}{q_h} + a_i \leq x_{i,h}$ and $\Delta x_{i,l} \geq -x_{i,l}$.

Essentially, the manager exchanges between the two types of loans under a constraint imposed by safe debt outstanding and a short-sale constraint. Note that the arrival of negative news updates loan h's and loan l's fundamental values to 1 and π, respectively. I proceed to solve this problem based on the following lemma.

Lemma 2. *In the negative-news stage, the ratio of secondary market loan prices is lower than the ratio of fundamental values:* $\frac{q_l}{q_h} \leq \pi$.[11]

Lemma 2 shows that in bad times, secondary market trades exert pressure on loan prices, pushing them away from fundamental values. Whereas managers who face binding collateral constraints are forced to buy additional high-quality loans, other managers only care about returns. So for the unconstrained managers to be willing to trade as counterparties, low-quality loans, which are worse collateral, must offer a higher expected return. As such, the price-to-fundamental ratio of bad loans decreases relative to that of good loans.

The solution to (P1a) indicates that the manager's optimal trades lead to portfolio substitution:

$$\Delta x_{i,h} = a_i - x_{i,h}, \;\; \Delta x_{i,l} = -\frac{(a_i - x_{i,h})q_h}{q_l} \tag{3}$$

for any given $x_{i,h}$ and a_i. These trades reallocate loans among intermediaries. A manager

[11]This inequality will be shown to be generally strict in equilibrium, so I ignore the corner case (i.e., $\frac{q_l}{q_h} = \pi$) throughout this section.

with $a_i > x_{i,h}$ optimally sells just enough bad loans to increase the holding of good loans and keep debt safe. Such collateral substitution is costly to equity holders (including the manager) because it not only decreases portfolio volatility, but also moves prices in unfavorable directions. By contrast, a manager with $a_i < x_{i,h}$ sells its extra good loans and buys bad loans to profit from the deviation of loan prices from fundamentals.

3.3 Balance Sheet Choices

This subsection characterizes the manager's optimal lending and financing choices at $t = 0$ for given loan prices. Optimal secondary market trades in (3) imply that an intermediary's equity holders' continuation value v in the positive- and negative-news stages are $x_i R - a_i$ and $\pi\Big(x_{i,l} + (x_{i,h} - a_i)\frac{q_h}{q_l}\Big)$, respectively. By no arbitrage, $0 < q_l < q_h$, and initial collateral constraint (ICC) is equivalent to

$$a_i \leq x_i - x_{i,l} + x_{i,l}\frac{q_l}{q_h}. \tag{ICCa}$$

Substitute v into (P0), the manager's lending and financing problem becomes

$$\max_{x_i, a_i} \; p(x_i R - a_i) + (1-p)\pi\Big((x_i - x_{i,l} - a_i)\frac{q_h}{q_l} + x_{i,l}\Big) - \Big(c(x_i) - (1 + \gamma - \xi_i)a_i\Big) \tag{P0a}$$

subject to constraints (ICCa) and $a_i \geq 0$.[12] Let η_i and μ_i respectively be the Lagrangian multipliers of these constraints. The manager's Kuhn-Tucker conditions for optimality are

$$pR + (1-p)\pi\frac{q_h}{q_l} - c'(x_i) + \eta_i = 0, \tag{4}$$

$$\gamma - \xi_i - (1-p)\Big(\pi\frac{q_h}{q_l} - 1\Big) - \eta_i + \mu_i = 0, \tag{5}$$

and

$$\eta_i \geq 0, \eta_i\Big(a_i - \Big(x_{i,h} + x_{i,l}\frac{q_l}{q_h}\Big)\Big) = 0, \mu_i \geq 0, \mu_i a_i = 0. \tag{6}$$

[12] Assumption 2 guarantees that the realization of $\tilde{x}_{i,l} = x_{i,l}$ does not affect the choice of x_i, so the realized quantity is used in the optimization problem.

Because of the price pressure in bad times, replacing deteriorated loans is costly, and providing collateral to others is profitable. Equation (5) states that a manager's financing choice is based on a tradeoff between the funding benefit of safe debt, $\gamma - \xi_i$, and the expected profit from collateral provision, $(1-p)\Big(\pi\frac{q_h}{q_l} - 1\Big)$. It follows that two cases are possible. In the first case, the benefit is less than the profit, hence no safe debt would be issued ($\mu_i > 0$), and the collateral constraint would be slack ($\eta_i = 0$). Accordingly, the lending choice in (4) is simply based on a tradeoff between the expected payoff and the marginal cost of investment.

In the second case, the funding benefit exceeds the profit, and collateral constraint (ICCa) binds. On the liability side, the manager fully uses safe debt capacity to exploit cheap financing. On the asset side, as characterized by Equation (4), lending exceeds what the payoff–cost tradeoff suggests. The additional investment, captured by $\eta_i = \gamma - \xi_i - (1-p)(\pi\frac{q_h}{q_l} - 1) > 0$, reflects the collateral value of loans. As η_i decreases in ξ_i, a manager with better securitization technology originates more loans to back a larger safe tranche.

3.4 Equilibrium Market Structure and Safe Asset Supply

I proceed to analyze the market structure that is determined by intermediary balance sheets. A key metric in the equilibrium's feedback loop is price ratio $\frac{q_l}{q_h}$, which captures the marginal rate of collateral substitution. When this ratio is higher, replacing deteriorated loans is less costly, and providing collateral to others is less profitable, so issuing safe debt is more attractive. However, safe debt issuance increases the secondary market demand for (supply of) high-quality (low-quality) loans, and the market cannot clear unless the price ratio drops sufficiently. These equilibrium forces drive managers' balance sheet choices.

The market-clearing condition (2) and optimal trades in (3) imply an equilibrium relationship between the aggregate quantities of safe debt and loans:

$$\int_i a_i \,\mathrm{d}i = \int_i x_{i,h} \,\mathrm{d}i. \tag{7}$$

Intuitively, safe debt cannot exceed the worst possible loan payoffs, and intermediaries always jointly use up the aggregate safe debt capacity. Equation (7) reflects this aggregate relationship given the assumed payoff distributions.

I characterize the equilibrium in two steps. First, I consider a knife-edge case in which all managers are homogeneous. This special case provides intuition useful for understanding the competitive allocation and its efficiency. Next, I analyze the equilibrium market structure when managers have different securitization technology.

3.4.1 Equilibrium without Heterogeneity

Suppose managers are identical ex ante: $\xi_i = \xi^* \in [0, \gamma)$ for all $i \in \mathcal{I}$. The economy has multiple equilibria that share the same price ratio and aggregate quantities.

Lemma 3. *If managers are homogeneous, the total supply of safe assets is the same as in static securitization. Intermediaries share the same lending choice but can have different financing choices, and price ratio* $\frac{q_l}{q_h} = \frac{(1-p)\pi}{1-p+\gamma-\xi^*} < \pi$.

The intuition behind this result follows from the tradeoff in Equation (5). When mangers are homogenous, secondary market prices must adjust until everyone is indifferent about financing choices. That is, the benefit of issuing one more unit of safe debt must equal the profit of providing one more unit of collateral to others. This indifference condition implies that lending choices, and hence by Equation (7), the supply of safe assets, coincide with the setting where nobody provides collateral to others, namely, the static benchmark.

3.4.2 Equilibrium with Heterogeneity in Securitization Technology

For various reasons, asset managers may be heterogeneous in securitization technology. My analysis of the equilibrium under this heterogeneity focuses on a setting where manager types are continuous. This setting allows for a clean characterization that incorporates intuition from settings with discrete manager types, for which I provide an analysis in Subsection IA.4.1 of the Internet Appendix.

Without loss of generality, let manager i's safe debt issuance cost be $\xi_i = 2\xi i$ for constant $\xi \in (0, \gamma/2)$. Managers are thus ranked by issuance cost. Given loan prices, a manager with a lower issuance cost benefits strictly more from issuing safe debt than a manager with a higher issuance cost, so the constraints on safe debt choices in (P1a) will bind for almost everyone. Hence, financing choices at the extensive margin can be summarized by a cutoff $\lambda \in [0, 1]$: manager $i \leq \lambda$ issues safe debt, and manager $i > \lambda$ issues only equity. By construction, the cutoff type is indifferent between issuing safe debt and providing collateral to others:

$$\gamma - \xi_\lambda = (1-p)\Big(\pi\frac{q_h}{q_l} - 1\Big). \tag{8}$$

The equilibrium is reached when the price ratio adjusts to (i) satisfy this indifference condition and (ii) clear the secondary market.

Proposition 1 (Competitive Equilibrium)**.** *There exists a unique equilibrium.*[13] *In equilibrium, there is an interior cutoff $\lambda^{CE} \in (0, 1)$ such that (i) managers below the cutoff promise to maintain collateral quality and fully use safe debt capacity, and (ii) managers above the cutoff do not issue any safe debt. Formally,*

$$x_i^{CE} = \begin{cases} c'^{-1}\Big(pR + 1 - p + \gamma - \xi_i\Big), & \text{if } i \leq \lambda^{CE} \\ c'^{-1}\Big(pR + 1 - p + \gamma - \xi_{\lambda^{CE}}\Big), & \text{if } i > \lambda^{CE} \end{cases}, \tag{9}$$

$$a_i^{CE} = \begin{cases} x_i^{CE} - x_{i,l} + x_{i,l}\frac{q_l}{q_h}, & \text{if } i \leq \lambda^{CE} \\ 0, & \text{if } i > \lambda^{CE} \end{cases}, \tag{10}$$

and

$$\frac{q_l}{q_h} = \frac{(1-p)\pi}{1 - p + \gamma - \xi_{\lambda^{CE}}}. \tag{11}$$

[13]The uniqueness is with respect to balance sheet quantities and price ratio. The levels of loan prices are not uniquely identified. Subsection IA.3.1 of the Internet Appendix generalizes the setting to allow for identified price levels.

Proposition 1 characterizes intermediary balance sheets and the market structure. In equilibrium, two distinct groups of intermediaries, resembling CLOs and non-securitized lenders, emerge and coexist. The first group optimally exhaust safe debt capacity, which they maximize by promising to replace the entirety of deteriorated loans after negative news.[14] This promise allows the managers to enjoy high payoffs after positive news.

By contrast, managers in the second group completely give up issuing safe debt. They do so because market-clearing loan prices deviate from fundamental values (i.e., $q_l/q_h < \pi$), which makes providing collateral in the secondary market more attractive to them. As the profit of collateral provision does not depend on the manager's safe debt issuance cost, intermediaries in this group have identical lending choices.

Corollary 1.1. *The market produces a greater supply of safe assets than the static benchmark.*

An immediate corollary of Proposition 1 is that the market produces more safe assets than the static benchmark. Consistent with Equation (7), this greater safe asset supply is accompanied by a larger quantity of high-quality loans. Non-securitized lenders, despite having no need for collateral, lend more than they would in static securitization: Equation (9) shows that $x_i^{CE} > x_i^{STA}$ for every $i > \lambda^{CE}$. They do so because the anticipated profits from secondary market trading increase the marginal return from loan origination. Moreover, as safe debt is issued by managers with relatively better securitization technology, the market also has a lower average cost of safe asset production.

Figure 3 presents a numerical illustration of the equilibrium and compares the market structure with and without a secondary market. Unlike that everyone issues safe debt in static securitization, the market has an interior mix of intermediaries with distinct liabilities. Managers with better securitization technology ($i \leq \lambda^{CE}$) operate CLOs. Their increased safe debt capacity from dynamic collateral management can be seen in the wedge between $\mathbb{E}[a_i^{CE}]$ and $\mathbb{E}[a_i^{STA}]$. From an equilibrium perspective, the increase in safe asset supply comes

[14]To see this, substitute the safe debt choice (10) into optimal trades in (3).

from the increased lending of the non-securitized lenders ($i > \lambda^{CE}$), which is reflected by the wedge between x_i^{CE} and x_i^{STA}.

3.5 Model Extensions

My setup's focus on long-term debt leaves the question open as to why CLOs do not issue short-term debt, which can be made safe by liquidating loans and repaying debtholders in bad times. To address this question, I analyze two extensions in Section IA.3 of the Internet Appendix. First, I allow debt maturity choices and loan trades to be jointly determined with secondary market purchases by outside investors.[15] Intuitively, long-term contracts help CLOs maximize and maintain cheap leverage when it is costly for outsiders to participate and buy liquidated loans. Second, I discuss contractual frictions, under which managers strategically respond to collateral constraints. I show that requiring over-collateralization can constrain managers from reaching for yield, but the informativeness of verifiable proxies for loan quality is crucial to the safety of long-term debt backed by dynamic portfolios.

4 Welfare and Policy Implications

This section analyzes the equilibrium's welfare properties and their policy implications.

4.1 Social Planner's Problem

Consider a planner who controls every intermediary's lending and financing choices in period $t = 0$. The planner respects all the individual constraints faced by asset managers but does not take secondary market prices as given. Instead, by choosing quantities, he can target

[15] Outsiders (e.g., distressed debt funds) differ from intermediaries in that they only invest in liquidated assets in the secondary market and do not participate in loan origination.

specific prices that (i) admit his choices at $t = 0$ and (ii) clear the secondary market at $t = 1$. Moreover, he can redistribute payoffs among agents after uncertainty resolves at $t = 2$.

The market-clearing condition (2) imposes an additional constraint on the planner. As shown in the previous section, in the negative-news stage, binding constraints trigger loan trades in Equation (3). The secondary market clears if and only if $\int_i (a_i - x_{i,h})\,\mathrm{d}i \leq 0$, which gives rise to an aggregate collateral constraint.[16]

The planner's optimization problem is as follows. Let the total quantity of loans be $X = \int_i x_i\,\mathrm{d}i$. By law of large numbers, total low-quality loans $\int_i \tilde{x}_{i,l}\,\mathrm{d}i = x_L$. Since all agents have linear preferences, the planner's objective is to maximize the sum of expected payoffs and non-pecuniary benefits, minus the total costs of investment and safe debt issuance:

$$\max_{\{x_i, a_i\}_{i\in\mathcal{I}}} \quad pXR + (1-p)(X - x_L + \pi x_L) + \gamma A - \int_i \Big(c(x_i) + \xi_i a_i\Big)\,\mathrm{d}i \tag{SP}$$

$$s.t. \;\; A \leq X - x_L, \tag{ACC}$$

$$a_i \leq x_i - x_{i,l} + x_{i,l}\frac{q_l}{q_h}, \;\; \forall i \in \mathcal{I}, \tag{ICC}$$

$$a_i \geq 0, \;\; \forall i \in \mathcal{I}.$$

The aggregate collateral constraint (ACC) binds at the optimum: otherwise, there would be some i such that $a_i \in [0, x_{i,h})$, and since $\gamma > \xi_i$, increasing a_i would improve the objective, a contradiction to optimality. This implies that Equation (7) holds in the planned economy as well. Moreover, the slackness of individual collateral constraint (ICC) strictly increases in price ratio $\frac{q_l}{q_h}$, and loan prices do not affect the planner's objective or any other constraint. Therefore, a higher price ratio at least weakly improves the maximized total surplus, and the planner targets the highest market-clearing price ratio, which is, $q_l/q_h = \pi$.

Let ψ^{SP}, η_i^{SP}, and μ_i^{SP} be the Lagrangian multipliers for the three (sets of) constraints.

[16]When the inequality is strict, market clears if $q_l/q_h = \pi$, a corner case in which unconstrained managers are indifferent between the two types of loans.

For each $i \in \mathcal{I}$, the Kuhn-Tucker conditions for optimality are

$$pR + 1 - p - c'(x_i) + \psi^{SP} + \eta_i^{SP} = 0, \tag{12}$$

$$\gamma - \xi_i - \psi^{SP} - \eta_i^{SP} + \mu_i^{SP} = 0, \tag{13}$$

and

$$\eta_i^{SP} \geq 0, \eta_i^{SP}(a_i - x_{i,h} - x_{i,l}\pi) = 0, \mu_i^{SP} \geq 0, \mu_i^{SP} a_i = 0. \tag{14}$$

The planner internalizes the externalities of intermediary balance sheet choices. His choice of lending, as characterized by (12), accounts for both individual (η_i^{SP}) and social (ψ^{SP}) collateral values. The social collateral value captures that an intermediary's lending increases collateral available to others because loans can be reallocated in the secondary market. For financing choices characterized by (13), the planner trades off between the net benefit from producing safe assets and the opportunity cost of using the aggregate safe debt capacity. This social cost differs from a manager's private cost, which is calculated based on loan prices.

4.1.1 Welfare without Heterogeneity

Before the main welfare analysis, I revisit the knife-edge case in Lemma 3.

Lemma 4. *If managers are homogeneous, welfare is the same as in static securitization, and every competitive allocation is constrained efficient.*

In this case, reallocating loans before their payoffs realize does not improve welfare because no manager is better at securitizing loans than others. The planner cannot do better than the competitive market. Although he can change individual financing choices, which manager issues more or less safe debt is welfare-irrelevant given that all managers have the same securitization technology.

4.1.2 Welfare with Heterogeneity in Securitization Technology

Back to the setting where managers have different securitization technology, I now characterize the welfare properties of the competitive allocation.

Proposition 2 (Welfare Properties)**.** *Secondary market trading improves welfare, but relative to the constrained efficient benchmark, the competitive equilibrium has excessive entry into operating CLOs, underinvestment by non-securitized lenders, and an underproduction of safe assets. In particular, the planner's choices lead to price ratio* $\frac{q_l}{q_h} = \pi$ *and a unique cutoff* $\lambda^{SP} \in (0, 1)$ *such that (i) managers below the cutoff promise to maintain collateral quality and fully use safe debt capacity, and (ii) managers above the cutoff do not issue any safe debt. The allocations satisfy* $\lambda^{CE} > \lambda^{SP}$*,* $x_i^{CE} < x_i^{SP}$ *for* $i \in (\lambda^{SP}, 1]$*,* $A^{CE} < A^{SP}$*.*

Similar to the competitive market, the planner divides intermediaries into two distinct groups with different liabilities. Hence, cutoff λ^{SP} reflects the socially optimal entry into safe asset production. The social collateral value $\psi^{SP} = \gamma - \xi_{\lambda^{SP}}$ equals the net benefit of safe asset production by the cutoff type manager.

Because managers can always choose static securitization, by revealed preference, each of them is better off with secondary market trading. As investors break even, this implies a welfare improvement from specialization. The CLOs' promise to replace deteriorated loans transfers safe debt capacity between the two groups of intermediaries. Non-securitized lenders, who lack superior technology to securitize loans and thus have smaller loan portfolios, specialize in supplying collateral to others. Given diminishing returns to scale, their increased lending is relatively more productive. Meanwhile, the increase in collateral allows CLOs, who have better securitization technology, to produce a greater supply of safe assets.

Despite these benefits, the equilibrium is socially suboptimal. Figure 4 illustrates the differences between the competitive and planner's allocations. The planner assigns managers $i \in [0, \lambda^{CE}]$ to issue safe debt, and each of them on average issues more than their competitive quantities: $\mathbb{E}[a_i^{SP}] > \mathbb{E}[a_i^{CE}]$. Meanwhile, the planner forces the rest of intermediaries, which are equity financed, to lend more than their competitive levels: $x_i^{SP} > x_i^{CE}$. The area of the shaded region measures aggregate underinvestment, which, by Equation (7), equals the underproduction of safe assets.

4.2 Source of Inefficiency

The source of inefficiency is a pecuniary externality that arises CLOs' from dynamic collateral management: secondary market trades move loan prices, which in turn affect the collateral constraints commonly faced by all managers. Individual managers take loan prices as given when maximizing their own payoffs and do not internalize this externality. At the root of these price-dependent collateral constraints is the inability of agents to allocate current and future quantities with state-contingent contracts.

Given that managers are heterogeneous in securitization technology, allocative efficiency hinges on specialized safe asset production at both the intensive and extensive margins. However, competitive prices tighten collateral constraints in period $t = 0$ and prevent an ideal allocation. By internalizing the impact of individual choices on secondary market demand and supply, the planner achieves a price ratio that is unsustainable in the competitive market. This price ratio relaxes collateral constraints for all intermediaries, thereby allowing the planner to implement the ideal allocation.

An intuitive interpretation of the constrained inefficiency is that secondary market trading gives rise to a "public goods problem": managers privately prefer to exploit the collateral provided by others rather than originate loans that benefit others. The discrepancy between individual and social tradeoffs that causes the welfare loss is twofold.

Corollary 2.1. *Non-securitized lenders' private profit from the secondary market is lower than the social value of collateral:* $(1 - p)(\pi \frac{q_h}{q_l} - 1) < \psi^{SP}$.

On the asset side, there is an underinvestment by managers with inferior securitization technology.[17] The planner forces these managers to lend beyond their privately-optimal quantities, which allows other managers, who have superior technology, to issue more safe debt. In the competitive market, non-securitized lenders do not fully internalize the social value of collateral, and their lending choices limit the secondary market supply of high-quality loans, which results in the underproduction of safe assets.

Corollary 2.2. *For managers with mediocre securitization technology, the private benefit of issuing safe debt is lower than the social value of collateral:* $\gamma - \xi_i < \psi^{SP}$ *for* $i \in (\lambda^{SP}, \lambda^{CE})$.

On the liability side, safe debt issuance by managers with mediocre technology crowds out managers with better technology. Unlike the planner who cares about the efficiency of safe asset production, managers only care about their own cost of financing. As a result, too large a fraction of managers find it privately optimal to issue safe debt and operate CLOs, and the market produces safe assets at an inefficiently high average cost.

4.3 Policy Intervention

The previous subsection has shown that the equilibrium has excessive entry into safe asset production. In this subsection I analyze a particular policy that imposes an entry cost on managers who operate CLOs.

Suppose the policy incurs a cost $\zeta_i \in \mathbb{R}_+$ in the beginning of period $t = 0$ if manager i issues safe debt of any quantity $a_i > 0$.[18] For generality, the cost can be an arbitrary (weakly) increasing function of index $i \in \mathcal{I}$. This allows for any monotonic heterogeneity in the policy's impact: a less resourceful manager (i.e., having a higher safe debt issuance cost ξ_i) may also

[17] For managers in $[0, \lambda^{SP}]$, individually and socially optimal lending choices coincide, because they directly benefit from, and hence fully internalize, the collateral value of loans.

[18] This timing convention is for simplicity: the financing choice does not depend on the realization of idiosyncratic loan quality shock $\tilde{x}_{i,l}$.

face a higher policy-induced entry cost.

Under this policy, the manager's optimization problem in period $t = 0$ exhibits a discontinuity at $a_i = 0$. Given a binary choice between $a_i = 0$ and $a_i > 0$, I call the solution to (P0a) as *locally optimal* choices, which are characterized by conditions (4)–(6).

The policy distorts manages' financing choices, which in turn affect their lending choices. If an intermediary issues only equity, the manager's payoff is

$$V_i^e = y_i^e c'^{-1}(y_i^e) - c(c'^{-1}(y_i^e)) - (1-p)\pi x_L\left(\frac{q_h}{q_l} - 1\right), \tag{15}$$

where $y_i^e := pR + (1-p)\pi\frac{q_h}{q_l}$ is the marginal payoff of lending. If the intermediary issues a locally optimal quantity of safe debt, the manager's payoff is

$$V_i^d = y_i^d c'^{-1}(y_i^d) - c(c'^{-1}(y_i^d)) - (1-p)\pi x_L\left(\frac{q_h}{q_l} - 1\right) - x_L\eta_i\left(1 - \frac{q_l}{q_h}\right) - \zeta_i, \tag{16}$$

where $y_i^d := y_i^e + \eta_i$ is the manager's marginal payoff from lending, which includes collateral value η_i. Note that V_i^d is strictly increasing in η_i, which itself decreases in index i.[19] This implies that V_i^d is strictly larger for a smaller i. Since V_i^e is identical across i, others equal, only managers better at securitization issue safe debt.

Similar to previous sections, I use λ to denote the manager type that is *locally indifferent* between issuing safe debt and issuing only equity, so this type satisfies Equation (8). Since the indifference is local (i.e., it is conditional on $a_i > 0$) and does not reflect globally optimal choices, $\lambda \leq 1$ no longer has to hold; Instead, Lemma 2 and Equation (8) imply that λ is now upper bounded by $\frac{\gamma}{2\xi} > 1$. I denote the new cutoff type $\iota : [0, \frac{\gamma}{2\xi}] \mapsto [0,1]$ as a function of λ. This type satisfies a global indifference condition $V_{\iota(\lambda)}^d = V_i^e$.

Given loan prices and λ, there is a unique cutoff type $\iota(\lambda) < \lambda$ because $\zeta_i > 0$, and V_i^d is monotonic in i. When the entry cost approaches zero, the new cutoff converges to λ:

[19] The monotonicity in η_i can be seen from $\frac{\partial V_i^d}{\partial \eta_i} = c'^{-1}(y_i^d) - x_{i,l}(1 - \frac{q_l}{q_h}) > c'^{-1}(y_i^d) - x_{i,l} > 0$, where the last inequality follows from Assumption 2 because $y_d > pR + 1 - p$ by Lemma 2.

$\lim_{\bar{\zeta}\to 0+} \iota(\lambda) = \lambda$, where $\bar{\zeta} := \max_{i\in\mathcal{I}} \zeta_i$.

4.3.1 Equilibrium under an Entry Cost

Equilibrium under the entry cost policy can be defined similarly as Definition 1, except for that the manager's $t = 0$ problem takes the entry cost into consideration. The limiting property of $\iota(\lambda)$ indicates that, by continuity of the equilibrium, an interior equilibrium exists when $\bar{\zeta}$ is relatively small. Let λ^{ECP} and $\iota(\lambda^{ECP})$ respectively denote the locally indifferent type and the new cutoff type in equilibrium.

Proposition 3 (Equilibrium under an Entry Cost Policy)**.** *The entry cost policy reduces the fraction of CLOs, allows the remaining CLOs to issue more safe debt, but worsens the underproduction of safe assets:* $\iota(\lambda^{ECP}) < \lambda^{CE}$, $\mathbb{E}[a_i^{ECP}] > \mathbb{E}[a_i^{CE}]$ *for* $i \in [0, \iota(\lambda^{ECP})]$, $A^{ECP} < A^{CE}$.

Proposition 3 demonstrates that, while the policy reduces the entry into safe asset production, it may exacerbate the welfare loss through equilibrium effects. Since the entry cost deters managers from issuing safe debt, there is less pressure on secondary market prices in bad times. One the one hand, a higher price ratio relaxes the remaining CLOs' collateral constraints and allows them to issue more safe debt. On the other hand, providing collateral in the secondary market becomes less profitable, which discourages non-securitized lenders' investment. As a larger fraction of managers become non-securitized lenders and choose the decreased investment level, the policy leads to a reduction in collateral. In aggregate, the aforementioned increase in safe debt issuance is overwhelmed by the decrease in collateral, and the market ends up producing even fewer safe assets after the policy intervention.

Figure 5 compares the competitive allocation (same as in Figure 3) and the policy-distorted allocation. While managers $i \in [0, \iota(\lambda^{ECP})]$ do not change their lending choices, managers currently operating non-securitized lenders ($i \in [\iota(\lambda^{ECP}), 1]$) all lower their investment levels.

This leads to a reduction in aggregate high-quality loans, the quantity of which equals the area of the shaded region. Despite that every remaining CLO on average issues more safe debt than before ($\mathbb{E}[a_i^{ECP}] > \mathbb{E}[a_i^{CE}]$), the market underproduces safe assets to an even greater extent because of a shortage of collateral.

4.3.2 Credit Risk Retention Regulation

The above analysis sheds light on a controversial regulation. This regulation, generally referred to as Credit Risk Retention Rule, was initially proposed by 6 federal agencies (collectively, "regulators") in 2011 to implement the credit risk retention requirements of the Dodd-Frank Act. The rule requires "sponsors" of securitization transactions to retain at least 5% of un-hedged credit risk of collateral assets for any ABS. Sponsors can choose to retain 5% of each class of securities ("vertical retention"), a part of the first-loss interest that has a fair value of 5% of all ABS interests ("horizontal retention"), or any convex combination of the two.[20] The final rule became effective for residential mortgage-backed securities (RMBS) in December 2015 and for other ABS, including CLOs, in December 2016.

The rule's inclusion of CLOs received resistance from practitioners. The major complaint was that the rule imposes substantial operational and capital costs on asset managers and might drive them out of the CLO business. In November 2014, the Loan Syndications and Trading Association (LSTA), representing CLO managers, filed a lawsuit against the Federal Reserve and the SEC. In February 2018, the US Court of Appeals for the D.C. Circuit concluded that managers of open-market CLOs are not "sponsors" under the Dodd-Frank Act and are not subject to the requirements of the Risk Retention Rule. Consequently, CLO managers became exempted from the rule in May 2018.

Figure 6 presents the timing of the regulatory events and annual CLO entry rate in the US and European markets between 2000–2019. Before 2008, an average manager created

[20] See SEC Final Rules 34-73407 for more details.

more CLOs in the US than in Europe, but the time trends were similar. Perhaps due to the introduction of a similar rule in 2010, the European CLO market recovered slowly compared to the US market. After the finalization of the US risk retention rule in late 2014, there has been a salient drop in CLO entry.[21] This drop reversed quickly after the policy got revoked in early 2018. Section IA.5.2 of the Internet Appendix further examines the regulation's effect on CLO entry, which was predicted to be devastating by the LSTA and CLO managers.

This regulation's impact on CLO entry has important welfare implications. Proposition 3 has shown the equilibrium under an entry cost imposed by such a regulation. By reducing CLO entry, the rule potentially worsens the underproduction of safe assets and exacerbates the inefficiency of the leveraged loan market. Therefore, my analysis points to an unintended consequence. As the debate over whether the risk retention rule should be reapplied to the US market continues, policymakers should take this consequence into consideration.

5 Conclusion

Securitization transforms risky loans into tranches with different cash flow priorities. Facing the demand for safe assets, the private sector has created large quantities of senior tranches, but many of these securities defaulted in or after the 2008–2009 financial crisis. They failed because the quality of their underlying loans deteriorated and subsequently generated insufficient cash flows for repayment.

This paper analyzes an innovative form of securitization that is based on dynamic collateral management. So far, the most important application of this approach is in the rapidly growing leveraged loan market, where CLOs have been producing AAA-rated securities for more than two decades and have not ever failed.

[21]The US policy became effective in 2016, and this response is likely due to the fact that CLO equity enjoys the option to refinance debt tranches after 2–3 years of non-call period, and the anticipated retention cost at refinancing deterred CLO entry.

The assets and liabilities of CLOs are dynamically governed by a contract design that obligates the portfolio managers to maintain collateral quality through secondary market trading. To understand how this contract facilitates safe asset production, I develop an equilibrium model in which intermediaries flexibly choose external financing and can commit to future loan trades. My analysis explains the unique market structure whereby CLOs and non-securitized lenders coexist and trade as counterparties in economic downturns. While the market produces more safe assets than in static securitization, the competitive equilibrium tends to be constrained Pareto inefficient. The framework presented in this paper can be useful for understanding the leveraged loan market and examining policy interventions.

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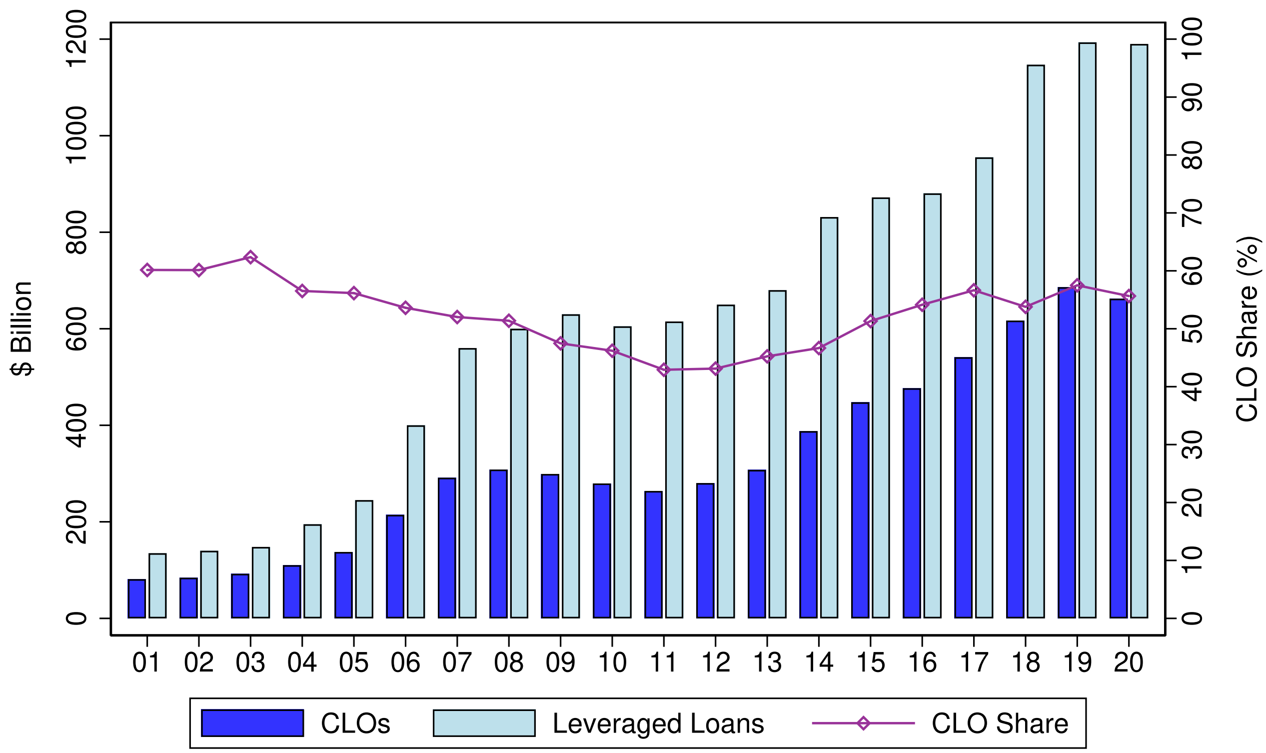

Figure 1: **Leveraged loans and CLOs outstanding, 2001–2020.**
This figure plots annual aggregate par values outstanding for leveraged loans (i.e., institutional term loan facilities) and CLOs in the US market. Data source: SIFMA.

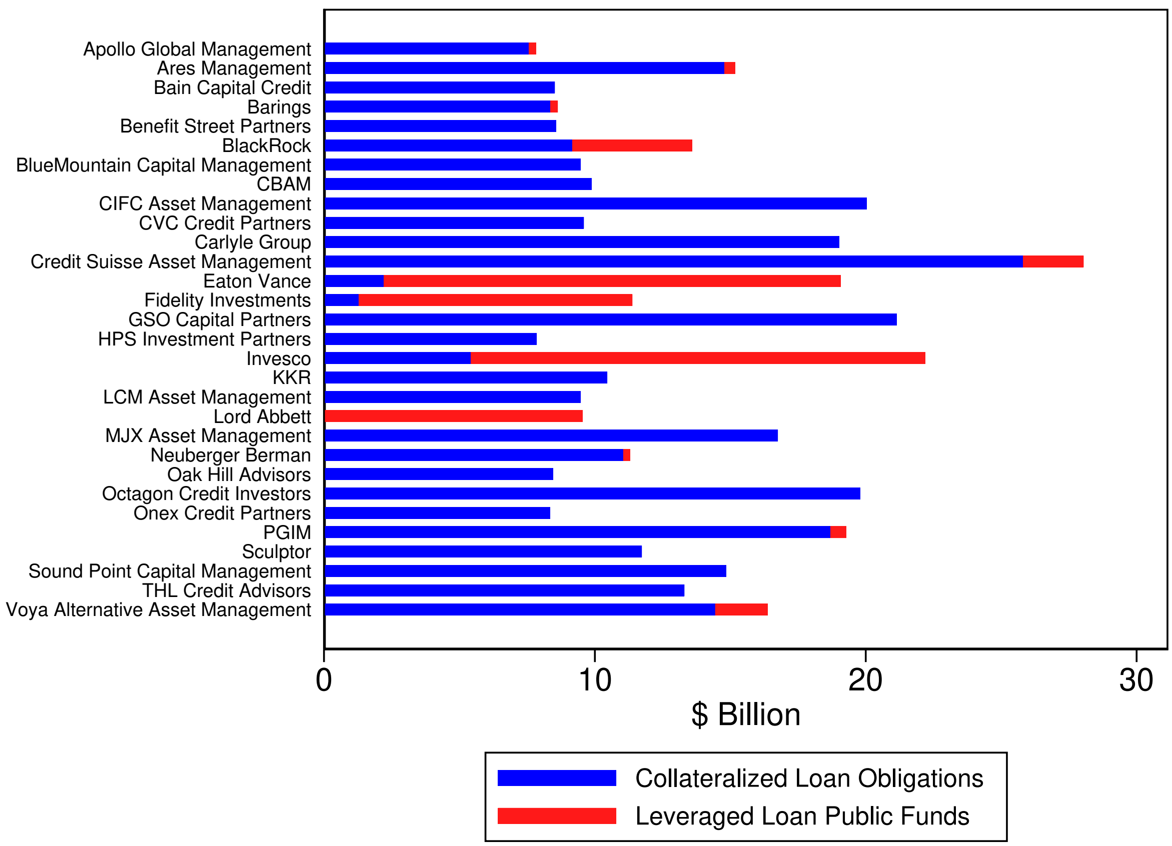

Figure 2: **Asset managers and nonbank intermediaries.**
This figure presents the size of assets under management for US CLOs and leveraged loan funds (open-end and closed-end mutual funds and exchange-traded funds) operated by the 30 largest asset managers at the end of 2019. Data come from Creditflux CLO-i, Morningstar, and the SEC's Form ADV databases.

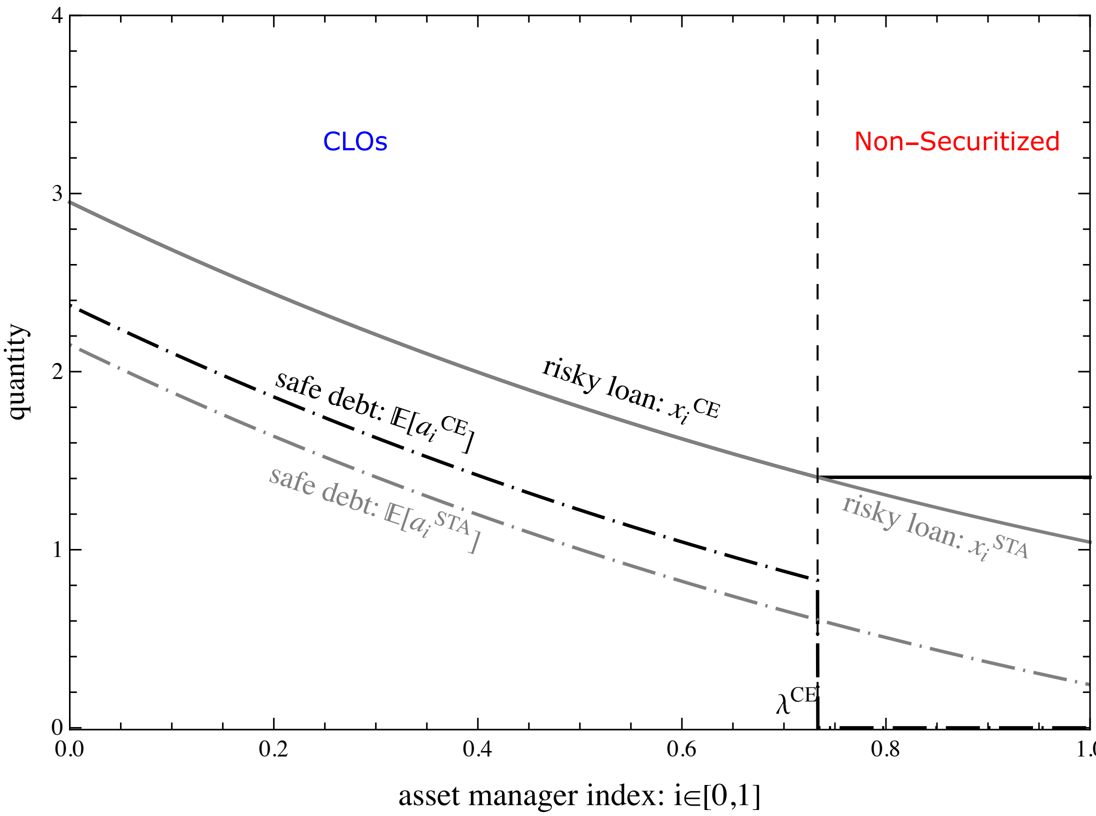

Figure 3: **Competitive equilibrium.**
This figure illustrates the lending and financing choices in competitive equilibrium. Superscripts CE and STA indicate the equilibrium with a secondary market and the static benchmark, and x_i and $\mathbb{E}[a_i]$ denote manager i's quantities of loan origination and average safe debt issuance, respectively. Functional form and parameter values: $c(x) = x^{1.2}$, $p = 0.95$, $R = 1.2$, $\pi = 0.8$, $\gamma = 0.3$, $\xi = 0.14$, $x_L = 0.8$.

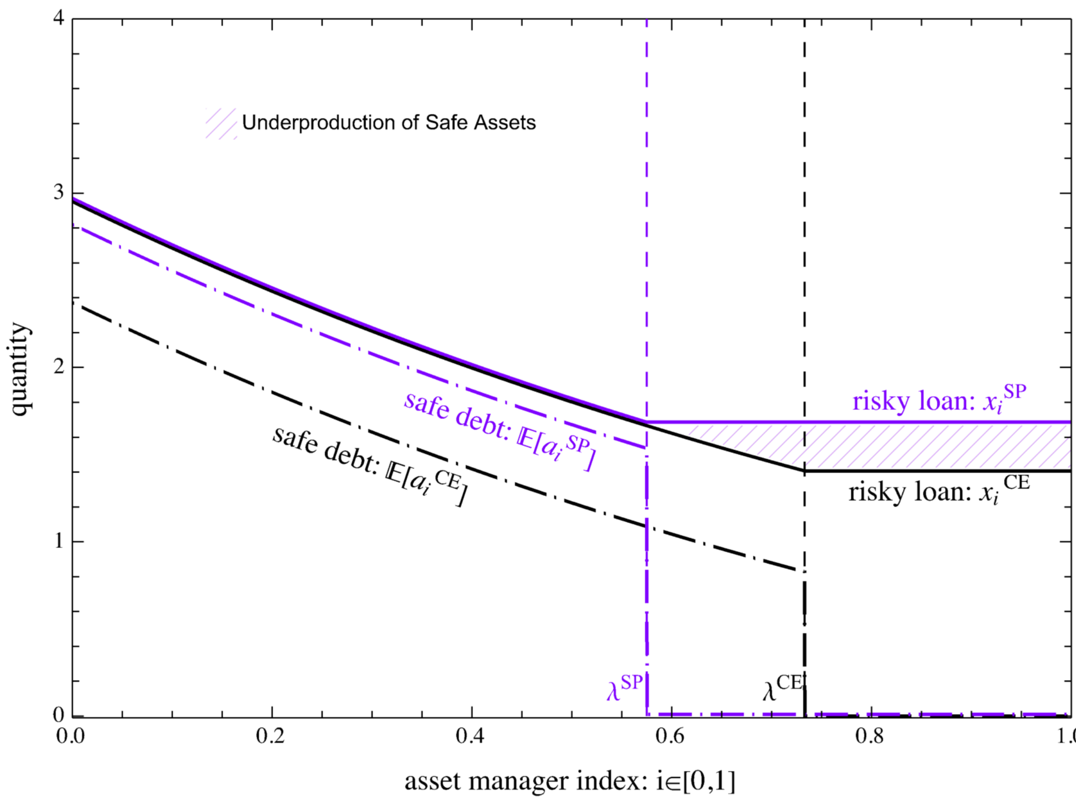

Figure 4: **Constrained inefficiency.**
This figure illustrates the constrained efficiency of the equilibrium. Superscripts CE and SP indicate the competitive and the social planner's allocations, and x_i and $\mathbb{E}[a_i]$ denote manager i's quantities of loan origination and average safe debt issuance, respectively. The area of the shaded region represents the quantity of underproduction of safe assets in equilibrium. Functional form and parameter values are the same as in Figure 3.

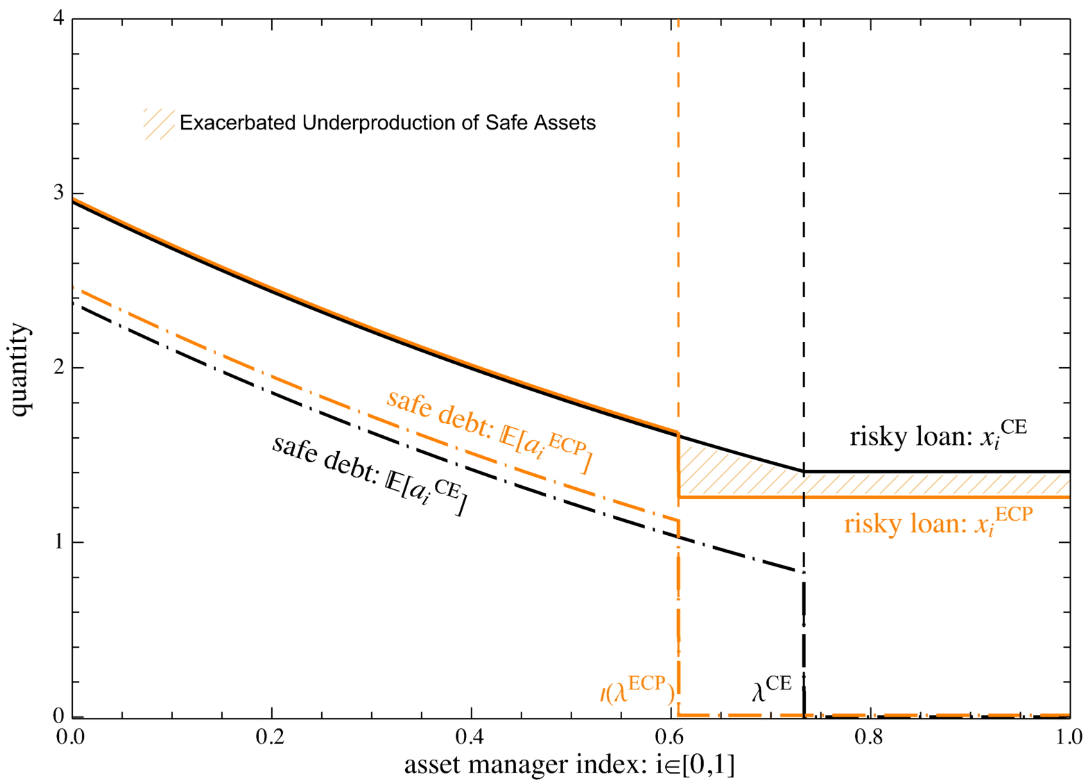

Figure 5: **Equilibrium under the entry cost policy.**
This figure illustrates the equilibrium when an entry cost is imposed any intermediaries that issue safe debt. Superscripts CE and ECP indicate the original and policy-distorted competitive allocations, and x_i and $\mathbb{E}[a_i]$ denote manager i's quantities of loan origination and average safe debt issuance, respectively. The area of the shaded region represents the quantity of incremental underproduction of safe assets in distorted equilibrium. Entry cost $\zeta_i = \zeta i$, $\zeta = 0.1$, and other functional form and parameter values are the same as in Figure 3.

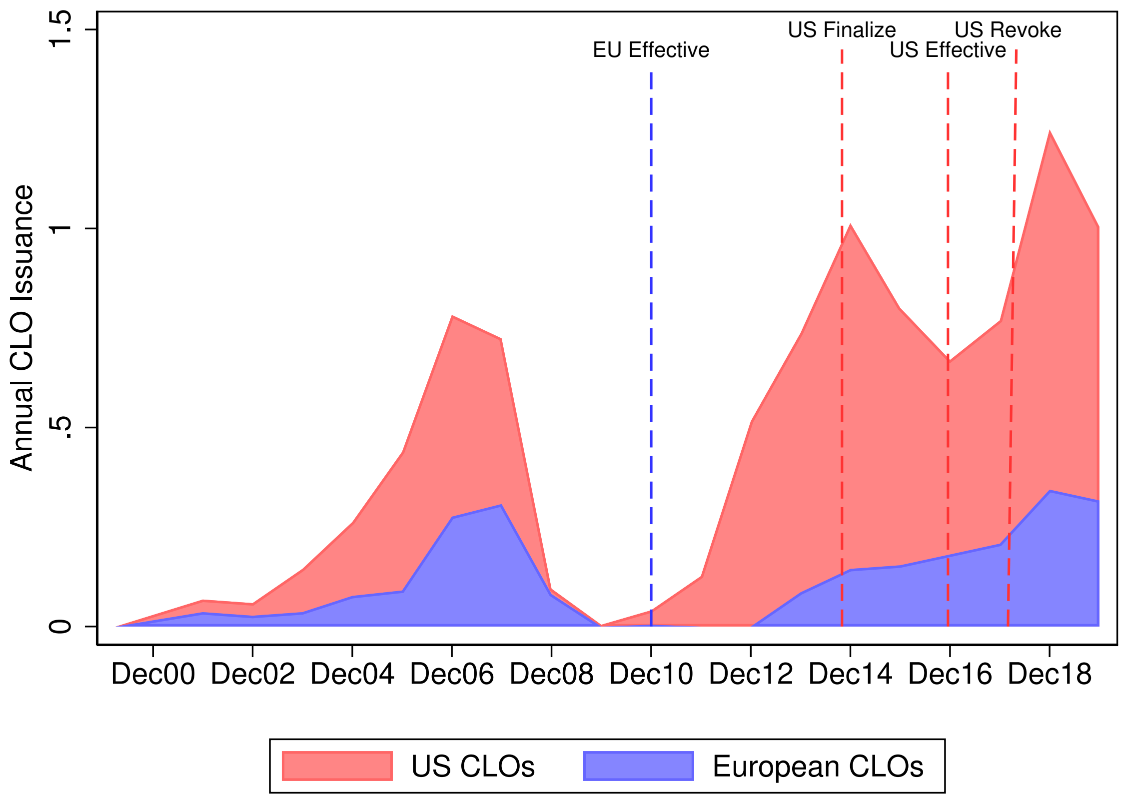

Figure 6: **Risk retention and CLO entry in the US and European markets.**
This figure plots the timing of regulatory events and annual average number of an asset manager's CLO deals issued in the US and European markets. The Capital Requirements Directive II introduced in Europe requires 5% risk retention for all new securitization deals issued after January 2011. These provisions were superseded by an equivalent requirement in Capital Requirements Regulation in January 2014. In the US, the Credit Risk Retention Rule, finalized in October 2014 to require a 5% risk retention, became effective for CLOs in December 2016 and got revoked in February 2018.

Appendix: Proofs

Proof of Lemma 1. Without a secondary market, $\Delta x^s_{i,h} = \Delta x^s_{i,l} = 0$ for all i, s, and constraint (ICC) becomes $a_i \leq x_{i,h}$. The objective in (P0) is strictly increasing in a_i by Assumption 1, so this constraint binds at a_i^{STA}. The first-order condition with respect to x_i is $pR + 1 - p - c'(x_i) + \gamma - \xi_i = 0$, which characterizes the lending choice x_i^{STA}.

Proof of Lemma 2. Suppose $\frac{q_l}{q_h} > \pi$, the objective in program (P1a) would be strictly decreasing in $\Delta x_{i,l}$, and the optimal choice would be $\Delta x_{i,l} = -x_{i,l}$ for all $i \in \mathcal{I}$. This contradicts the low-quality loan's market clearing condition (2).

Proof of Lemma 3. The complementary slackness condition (6) requires $\eta_i, \mu_i \geq 0$ to not be simultaneously positive for any $i \in \mathcal{I}$. Suppose $\xi_i = \xi^*$ for all i, the manager's first-order condition (5) implies that $\eta_i - \mu_i$ is a constant across all i. If $\eta_i > 0$ for all i, or if $\mu_i > 0$ for all i, Equation (7) would be violated, so $\eta_i = \mu_i = 0$ for all $i \in \mathcal{I}$. This implies that $\frac{q_l}{q_h} = \frac{(1-p)\pi}{1-p+\gamma-\xi^*}$, $x_i = c'^{-1}(pR + 1 - p + \gamma - \xi^*)$, and any $\left\{a_i : a_i \leq x_{i,h} + x_{i,l}\frac{q_l}{q_h}\right\}_{i \in \mathcal{I}}$ that satisfies Equation (7) is an equilibrium. Also, by Equation (7), the supply of safe assets is the same as in the static benchmark because here x_i equals x_i^{STA} in Lemma 1 for all $i \in \mathcal{I}$.

Proof of Proposition 1. If a competitive equilibrium exists, the cutoff type's indifference condition (8) implies that

$$\frac{q_l}{q_h} = \frac{(1-p)\pi}{1-p+\gamma-\xi_\lambda}, \tag{A.1}$$

which is well-defined and strictly positive by Assumption 1. The two groups of intermediaries' lending choices follow from substituting η_i and (A.1) into (4). Given their optimal safe debt choices and secondary market trades in (3), the market clearing condition (2) can be rewritten as

$$\frac{q_l}{q_h}\int_0^\lambda x_{i,l}\,\mathrm{d}i = \int_\lambda^1 x_{i,h}\,\mathrm{d}i. \tag{A.2}$$

By law of large numbers, $\int_0^\lambda x_{i,l}\,\mathrm{d}i = \lambda x_L$, and $\int_\lambda^1 x_{i,h}\,\mathrm{d}i = (1-\lambda)(x_i - x_L)$. Both $\frac{q_l}{q_h}$ and x_i are functions of λ, so Equations (A.1) and (A.2) are equivalent to an aggregate excess demand condition $\chi^{CE}(\lambda) = 0$, where $\chi^{CE} : [0,1] \mapsto \mathbb{R}$ is defined as:

$$\chi^{CE}(\lambda) = \frac{\lambda(1-p)\pi x_L}{1-p+\gamma-2\xi\lambda} - (1-\lambda)\Big(c'^{-1}\Big(pR+1-p+\gamma-2\xi\lambda\Big) - x_L\Big). \tag{A.3}$$

The excess demand function satisfies $\chi^{CE}(0) = x_L - c'^{-1}(pR+1-p+\gamma) < 0$ by Assumption 2 and $\chi^{CE}(1) = \frac{(1-p)\pi x_L}{1-p+\gamma-2\xi} > 0$, so the existence of a real root follows from intermediate value theorem. Moreover, by the properties of c, χ^{CE} is continuous and strictly increasing on $[0,1]$, so the root is unique.

Proof of Lemma 4. Substitute the equilibrium price ratio in Lemma 3 into problem (P0a), it follows that the objective is independent to a_i. Manager welfare is the same as in static securitization because the lending choice x_i coincides with that in Lemma 1.

Apply similar arguments as in the proof of Lemma 3 to the planner's optimality conditions (12)-(14), it follows that $\eta_i^{SP} = \mu_i^{SP} = 0$, $\psi^{SP} = \gamma - \xi^*$, $x_i = c'^{-1}(pR+1-p+\gamma-\xi^*)$, and any $\{a_i : a_i \le x_{i,h} + x_{i,l}\pi\}_{i\in\mathcal{I}}$ that satisfies the binding aggregate collateral constraint (ACC) is constrained efficient. Note for any realization of $\{\tilde{x}_{i,l}\}_{i\in\mathcal{I}}$, the set of competitive allocation is a subset of the planner's allocation, so every competitive allocation is constrained efficient.

Proof of Proposition 2. I first show that every manager is strictly better off with secondary market trading and then characterize the constrained inefficiency of the equilibrium.

Manager Welfare. The manager payoff in static securitization is

$$V_i^{STA} = px_i^{STA}R + (1-p)(x_i^{STA} - x_{i,l} + \pi x_{i,l}) + (\gamma - \xi_i)a_i^{STA} - c(x_i^{STA}). \tag{A.4}$$

For any manager $i \in [0, \lambda^{CE})$, $x_i^{CE} = x_i^{STA}$ and $a_i^{CE} > a_i^{STA} = x_i^{STA} - x_{i,l}$. Substitute x_i^{CE}, a_i^{CE} into (P0a) and collect terms, it follows that $V_i^{CE} = V_i^{STA} + (\gamma - \xi_i)(a_i^{CE} - a_i^{STA}) > V_i^{STA}$. For any manager $i \in (\lambda^{CE}, 1]$, $x_i^{CE} > x_i^{STA}$, $a_i^{CE} = 0$, and $\gamma - \xi_i < (1-p)(\pi\frac{q_h}{q_l} - 1)$. Define

$\phi^{CE} = (1-p)(\pi\frac{q_h}{q_l} - 1)$ and $\phi^{STA} = \gamma - \xi_i$. Recognize that x_i^{CE} and x_i^{STA} are solutions to

$$V_i(\phi_i) = \max_{x_i} \; px_iR + (1-p)(x_i - x_{i,l} + \pi x_{i,l}) + \phi_i(x_i - x_{i,l}) - c(x_i). \tag{A.5}$$

By the envelope theorem, $\frac{\partial V_i}{\partial \phi_i} > 0$, so $\phi^{CE} > \phi^{STA}$ implies $V_i^{CE} > V_i^{STA}$.

Constrained Inefficiency. Individual collateral constraint (ICC) faced by the planner must be slack for a proper subset of intermediaries, otherwise aggregate collateral constraint (ACC) would be violated. By monotonicity of ξ_i in i, Equation (13) implies that there exists some $\lambda \in (0,1)$, such that $\eta_i^{SP} = \gamma - \xi_i - \psi^{SP} > 0, \mu_i^{SP} = 0$ for each $i \in [0, \lambda)$, and $\eta_i^{SP} = 0, \mu_i^{SP} > 0$ for each $i \in (\lambda, 1]$. The planner is indifferent about debt issuance for the cutoff type $i = \lambda$, which satisfies $\psi^{SP} = \gamma - \xi_\lambda$. This implies the planner's financing choices

$$a_i^{SP} = \begin{cases} x_i^{SP} - x_{i,l} + x_{i,l}\pi, & \text{if } i \leq \lambda^{SP} \\ 0, & \text{if } i > \lambda^{SP} \end{cases}. \tag{A.6}$$

The planner's lending choices follow from substituting $\eta_i^{SP} = \max\{\xi_\lambda - \xi_i, 0\}$ and $\psi^{SP} = \gamma - \xi_\lambda$ into (12):

$$x_i^{SP} = \begin{cases} c'^{-1}\Big(pR + 1 - p + \gamma - \xi_i\Big), & \text{if } i \leq \lambda^{SP} \\ c'^{-1}\Big(pR + 1 - p + \gamma - \xi_{\lambda^{SP}}\Big), & \text{if } i > \lambda^{SP} \end{cases}, \tag{A.7}$$

Given the cutoff property, the binding constraint (ACC) is equivalent to

$$\pi \int_0^\lambda x_{i,l} \, \mathrm{d}i = \int_\lambda^1 (x_i - x_{i,l}) \, \mathrm{d}i, \tag{A.8}$$

and the cutoff type λ solves $\chi^{SP}(\lambda) = 0$, where

$$\chi^{SP}(\lambda) = \pi\lambda x_L - (1-\lambda)\Big(c'^{-1}\Big(pR + 1 - p + \gamma - 2\xi\lambda\Big) - x_L\Big). \tag{A.9}$$

Similar to χ^{CE} defined in (A.3), $\chi^{SP} : [0,1] \mapsto \mathbb{R}$ is continuous, strictly increasing, and satisfies $\chi^{SP}(0) < 0$, $\chi^{SP}(1) > 0$. So cutoff $\lambda^{SP} \in (0,1)$ exists and is unique.

By construction, $\chi^{SP}(0) = \chi^{CE}(0)$ and $\chi^{SP}(\lambda) > \chi^{CE}(\lambda), \forall \lambda \in (0,1]$. This implies

$\chi^{SP}(\lambda^{CE}) > \chi^{CE}(\lambda^{CE}) = 0$, and hence $\lambda^{SP} \in (0, \lambda^{CE})$ by properties of χ^{SP}. Using aggregate relationship $A = X - x_L$, it follows that

$$A^{SP} - A^{CE} = X^{SP} - X^{CE} = \int_{\lambda^{SP}}^{1} (x_i^{SP} - x_i^{CE})\,\mathrm{d}i > 0 \tag{A.10}$$

because $x_i^{SP} > x_i^{CE}$ for any $i \in (\lambda^{SP}, 1]$ by Equations (9) and (A.7).

Proof of Proposition 3. If an equilibrium exists, the secondary market clearing condition (2) requires

$$\frac{q_l}{q_h} \int_0^{\iota(\lambda)} x_{i,l}\,\mathrm{d}i = \int_{\iota(\lambda)}^{1} x_{i,h}\,\mathrm{d}i. \tag{A.11}$$

The corresponding aggregate excess demand equation in the policy-distorted market is

$$\chi^{ECP}(\lambda) = \frac{q_l}{q_h} \int_0^{\iota(\lambda)} x_{i,l}\,\mathrm{d}i - \int_{\iota(\lambda)}^{1} (x_i - x_{i,l})\,\mathrm{d}i. \tag{A.12}$$

The proof is based on an auxiliary lemma on the relationship among equilibrium cutoff types. Given this lemma, the proposition follows immediately from the lending choices as functions of λ in Proposition 1 and the aggregate relationship in Equation (7).

Lemma A.1. $\iota(\lambda^{ECP}) < \lambda^{CE} < \lambda^{ECP}$.

I prove Lemma A.1 by contradiction in two steps. Both steps are constructed using the cutoff type condition (8), the market clearing condition (A.11), and individually optimal lending choices (9) in Proposition 1. For expositional convenience, I use superscript CE to label variables in competitive equilibrium and ECP to label variables in the equilibrium under the policy.

Step 1: Suppose $\lambda^{ECP} < \lambda^{CE}$, and hence $\iota(\lambda^{ECP}) < \lambda^{ECP} < \lambda^{CE}$. By Equation (8), this implies $(\frac{q_l}{q_h})^{ECP} < (\frac{q_l}{q_h})^{CE}$, and hence

$$\left(\frac{q_l}{q_h}\right)^{ECP} \int_0^{\iota(\lambda^{ECP})} x_{i,l}\,\mathrm{d}i < \left(\frac{q_l}{q_h}\right)^{ECP} \int_0^{\lambda^{CE}} x_{i,l}\,\mathrm{d}i < \left(\frac{q_l}{q_h}\right)^{CE} \int_0^{\lambda^{CE}} x_{i,l}\,\mathrm{d}i. \tag{A.13}$$

By Equation (9), the conjectured inequality also implies $x_i^{ECP} > x_i^{CE}$ for any $i > \lambda^{CE}$, which further implies

$$\int_{\iota(\lambda^{ECP})}^{1} (x_i^{ECP} - x_{i,l})\,\mathrm{d}i > \int_{\lambda^{CE}}^{1} (x_i^{ECP} - x_{i,l})\,\mathrm{d}i > \int_{\lambda^{CE}}^{1} (x_i^{CE} - x_{i,l})\,\mathrm{d}i. \tag{A.14}$$

Given Equation (A.2),

$$\left(\frac{q_l}{q_h}\right)^{CE} \int_0^{\lambda^{CE}} x_{i,l}\,\mathrm{d}i = \int_{\lambda^{CE}}^{1} (x_i^{CE} - x_{i,l})\,\mathrm{d}i, \tag{A.15}$$

so inequalities (A.13) and (A.14) jointly imply

$$\left(\frac{q_l}{q_h}\right)^{ECP} \int_0^{\iota(\lambda^{ECP})} x_{i,l}\,\mathrm{d}i < \int_{\iota(\lambda^{ECP})}^{1} (x_i^{ECP} - x_{i,l})\,\mathrm{d}i. \tag{A.16}$$

This contradicts that λ^{ECP} solves the zero aggregate excess demand equation $\chi^{ECP}(\lambda) = 0$. Clearly, $\lambda^{ECP} \neq \lambda^{CE}$ as $\iota(\lambda^{ECP}) < \lambda^{ECP}$, therefore $\lambda^{ECP} > \lambda^{CE}$ if an equilibrium exists.

Step 2: Suppose $\lambda^{CE} < \iota(\lambda^{ECP}) < \lambda^{ECP}$. Using similar arguments as in Step 1, these inequalities imply

$$\left(\frac{q_l}{q_h}\right)^{ECP} \int_0^{\iota(\lambda^{ECP})} x_{i,l}\,\mathrm{d}i > \int_{\iota(\lambda^{ECP})}^{1} (x_i^{ECP} - x_{i,l})\,\mathrm{d}i, \tag{A.17}$$

which is a contradiction, too. This completes the proof.