

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

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## Abstract

The possibility of ex-post collateral deterioration limits financial intermediaries' safe debt capacity. I study a model where intermediaries dynamically maintain collateral quality through secondary market loan trading. This credit enhancement increases the supply of safe assets beyond static securitization but generates a pecuniary externality that is not internalized in private lending and financing decisions. In equilibrium, too many intermediaries issue safe debt while underproducing safe assets overall. Simple policy interventions targeting only one side of intermediary balance sheets may exacerbate the inefficiency. My model provides a framework for analyzing the leveraged loan market and the regulation of collateralized loan obligations.

*JEL classifications:* G11, G23, G28

*Keywords:* safe asset, collateral substitution, pecuniary externality, leveraged loan, collateralized loan obligation, credit risk retention

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# 1 Introduction

Recent literature provides evidence that safe assets, namely debt instruments with very low probabilities of default, are priced at a premium ([Krishnamurthy and Vissing-Jorgensen, 2012](#); [Nagel, 2016](#); [Van Binsbergen, Diamond, and Grotteria, 2021](#)). The existence of this premium incentivizes the private sector to repackage risky loans into securities with different cash flow priorities, with the intention of creating safe senior tranches. Securitization started with mortgage loans in the 1970s and was gradually extended to other asset classes. An innovative form of securitization introduced in the late 1990s, collateralized loan obligations (CLOs), create AAA-rated securities backed by speculative-grade corporate loans (“leveraged loans”). The key innovation that distinguishes CLOs from other asset-backed securities is that the loan portfolios serving as collateral are actively managed. While the market for leveraged loans and CLOs has grown rapidly, the understanding of this innovation is still limited, and no framework exists to guide recent controversial policy changes.

This paper analyzes a model that explores the unique structure of the leveraged loan market, where asset managers operate two distinct types of intermediaries that lend in the primary market and trade in the secondary market. As [Figure 1](#) shows, US leveraged loans grew from \$130 billion to \$1.2 trillion between 2001—2020, and CLOs consistently held roughly half of these loans. Unlike the CLOs, the other type of intermediaries, including mutual funds and hedge funds, do not use their loan holdings as collateral to create safe securities. My model explains how the safety premium drives secondary market trades between the two types and in turn, contributes to the formation of this market structure. The model provides the key insight that this endogenous market structure creates a greater supply of safe assets than a setting that does not allow secondary market trading. I show, however, that the competitive equilibrium is not always socially optimal, and the market structure presents new policy challenges.

Increasing academic attention has been devoted to CLOs’ loan trades<sup>1</sup>, but what is the advantage of dynamic portfolios? The basic insight formalized by my analysis is that an intermediary can increase its safe debt capacity by promising to maintain collateral quality over time. Privately produced long-term debt is safe if it is continuously backed by a loan portfolio that will almost certainly generate enough cash flows to repay debtholders. The safe tranche’s size is thus limited by the possibility that an adverse shock will hit the economy, after which the portfolio’s cash flow realizations might be very low. Dynamic collateral addresses this limitation because selling deteriorated loans and buying good loans help prevent future cash flows from being too low. By reducing the portfolio’s payoff uncertainty, such “reverse risk shifting” trades protect debtholders at the expense of equity holders. Ex ante, a promise to perform these trades in bad times, if credible, allows for a larger safe tranche, so that equity holders can enjoy a lower cost of capital and expect a higher return.

As an important application of dynamic collateral management, CLO contracts obligate the managers to dynamically maintain portfolio quality through secondary market loan trading.<sup>2</sup> This contract design is enforced primarily based on third-party loan ratings. I present motivating evidence that during the COVID-19 crisis, CLOs’ intensive collateral substitution trades significantly mitigated portfolio quality deterioration. Similar effects of reverse risk shifting trades were observed during the 2008–2009 financial crisis ([Standard & Poor’s, 2016](#)), suggesting that the contract design consistently protects senior tranches in bad times. Since the marginal rate of collateral substitution hinges on secondary market prices, safe debt capacity increased by this approach is an equilibrium outcome.

My model integrates the approach into an equilibrium framework. In the model, investors derive a non-pecuniary benefit from riskless securities. The challenge faced by intermediaries trying to issue more safe debt is that risky loans are scarce (due to diminishing returns)

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<sup>1</sup>See the related literature section for a review of these studies.

<sup>2</sup>Recently, this contract design became popular in the commercial mortgage market, where 20% of securitization deals are structured as “CRE CLOs” in 2019.

and may deteriorate after origination (due to aggregate shocks). Deteriorated loans have a positive probability of paying off poorly, but which loans deteriorate is unknown ex ante. In bad times, a mismatch between assets and liabilities arises: Good loans have additional value as collateral, but they may be held by intermediaries with no safe debt outstanding. Dynamic collateral management is hence useful, as the secondary market allows intermediaries with different liabilities to trade and facilitates a contingent reallocation of risky loans. In equilibrium, intermediaries' ex-ante lending and financing choices affect their ex-post trades, which feed back to the balance sheet choices through loan prices.

This framework rationalizes the observed market structure as an equilibrium outcome. It is natural to ask why intermediaries investing in the same market have distinct liabilities, and, particularly, why a subset of intermediaries do not issue any safe debt. I show that such financing choices are endogenously driven by loan prices. Given a positive safety premium, every intermediary could profitably issue extra safe debt by promising to replace deteriorated loans. Unless providing liquidity in bad times (i.e., trading in the opposite direction) is sufficiently profitable, the secondary market demand for collateral will overwhelm the supply. So to clear the market, the price of bad loans decreases relative to the price of good loans until enough intermediaries want to provide liquidity and give up issuing safe debt. Therefore in equilibrium, two groups of intermediaries with distinct liabilities, like CLOs and mutual funds, coexist and trade as counterparties in the secondary market.

The benefits of this market structure arise from specialization. To understand this, a key observation is that the supply of safe assets cannot exceed the worst-possible aggregate loan payoff. So, reallocating loans before their payoffs realize improves welfare only if intermediaries are heterogeneous in securitization technology. Anticipating profitable loan trades, liquidity providers, who lack superior technology to securitize loans, lend more than in autarky, and their lending is relatively more productive; Meanwhile, the increased collateral allows safe debt issuers, who have better securitization technology, to produce more safe assets.

Despite the benefits, I show that this market structure suffers from an inherent inefficiency precisely when it is better than autarky. The source of inefficiency is a pecuniary externality: intermediaries ignore the equilibrium effects of their lending and financing choices on secondary market prices, which tighten safe debt issuers' binding collateral constraints. On the asset side, liquidity providers underinvest because the private profits of selling good loans are lower than the social benefits of collateral. On the liability side, issuing safe debt is privately optimal for intermediaries with mediocre securitization technology, but doing so is socially inefficient as it reduces collateral available to others. These two forces jointly depress the marginal rate of collateral substitution commonly faced by all safe debt issuers. As a result, the equilibrium has too many intermediaries issuing safe debt, but they underproduce safe assets relative to constrained efficiency. The welfare loss tends to be larger when the safety premium is higher and the technological heterogeneity is greater.

This constrained inefficiency of the competitive equilibrium creates the rationale for regulatory intervention, but the market structure presents unique policy challenges. In particular, simple policies targeting only one side of intermediary balance sheets may exacerbate the welfare loss through equilibrium effects. For example, given that too many intermediaries issue safe debt, one might conjecture that imposing an entry cost to reduce the fraction of safe debt issuers could improve welfare. By introducing an entry cost into the model, I show that correcting this over-entry problem exacerbates the underproduction of safe assets. This is because the reduction in safe debt issuers makes providing liquidity in the secondary market less profitable, which discourages liquidity providers' lending and thereby worsens the shortage of aggregate collateral. Generally, ideal policies should correct both sides of intermediary balance sheets to move the equilibrium towards constrained efficiency.

Through the lens of the model, I shed light on a controversial regulation. This regulation, called Credit Risk Retention Rule and finalized in the US in 2014, 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, it has led to both a decrease in the number of new CLOs and fierce resistance from practitioners. After winning a lawsuit against regulators in 2018, CLO managers were exempted from the rule, but whether to reapply it is still an ongoing debate. My analysis explains, from an equilibrium perspective, why this policy can cause unintended consequences that regulators should take into consideration.

My analysis of dynamic collateral management mainly focuses on long-term debt and 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 (e.g., [Stein, 2012](#)). In the final part of this paper, I explore two model extensions to address this question. First, I allow debt maturity choices and loan trades to be jointly determined with secondary market purchases by outsiders.<sup>3</sup> Intuitively, if outside buyers are scarce, asset managers prefer long-term contracts because such contracts maximize and maintain cheap leverage by preventing costly early liquidation. Second, I consider contractual frictions, under which managers strategically respond to collateral constraints. In that case, requiring over-collateralization can help constrain managers from reaching for yield, but the informativeness of verifiable proxies for loan quality is crucial to the feasibility of this credit enhancement.

The remainder of this paper proceeds as follows. Section [2](#) presents motivating empirical facts. Section [3](#) introduces the model and derives individual intermediaries' and social planner's choices. Section [4](#) characterizes the equilibrium and its welfare properties, based on which Section [5](#) analyzes the effects of policy interventions. Section [6](#) extends the model to explore the boundaries of dynamic collateral management. Section [7](#) concludes.

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<sup>3</sup>Outsiders (e.g., distressed debt funds) differ from intermediaries in that they only invest in liquidated assets in the secondary market, especially during market downturns.

## Related Literature

The framework presented in this paper helps organize and interpret a fast-growing body of literature on leveraged loans and CLOs. A number of empirical papers provide complementary evidence for the key ingredients of my model. [Cordell, Roberts, and Schwert \(2021\)](#) show that CLO equity tranches earn positive abnormal returns because debt tranches are priced at a premium, which is consistent with the view that the CLO structure arises as a response to the demand for safe assets caused by regulatory requirements ([Benmelech and Dlugosz, 2009](#)). Tracking the dynamics of loan ownership, [Giannetti and Meisenzahl \(2021\)](#) document that mutual funds and hedge funds buy deteriorated loans sold by CLOs, supporting that liquidity provision by other intermediaries is essential to CLOs' dynamic collateral management.<sup>4</sup> Consistent with the purpose of collateral substitution, [Fabozzi et al. \(2021\)](#) show that CLOs' simultaneous purchases and sales of loans are associated with lower portfolio quality deterioration. [Elkamhi and Nozawa \(2022\)](#) find that binding collateral constraints force CLOs to sell downgraded loans and that overlapped loan holdings among CLOs can cause pressures on loan prices. Such price pressures affect CLOs' collateral substitution in bad times, which in my model critically affects safe debt capacity. Moreover, existing evidence does not support the importance of adverse selection in this particular market.<sup>5</sup> So different from traditional theories of banking (e.g., [Rajan 1992](#); [Parlour and Plantin, 2008](#)) and securitization (e.g., [DeMarzo and Duffie, 1999](#); [DeMarzo, 2005](#)), my model abstracts from informational frictions and focuses on safe asset production in incomplete markets.

So far, this literature generally takes the observed CLO contracts as given. Several papers recognize that because the contracting is based on imperfect proxies for a loan's quality

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<sup>4</sup>My analysis also suggests that in equilibrium, part of the rents earned by CLOs pass through secondary market trades to these liquidity providers.

<sup>5</sup>[Shivdasani and Wang \(2011\)](#) and [Benmelech, Dlugosz, and Ivashina \(2012\)](#) find that loans financed by CLOs do not perform worse than loans retained by banks, and [Blickle et al. \(2020\)](#) show that loans sold by lead arrangers are less likely to become non-performing subsequently. See [Cordell, Roberts, and Schwert \(2021\)](#) for a more detailed discussion on this issue.

and value, CLO managers may strategically respond by selectively selling loans that are marked-to-market (Elkamhi and Nozawa, 2022; Kundu, 2021) or traded at higher prices (Loumioti and Vasvari, 2019; Nicolai, 2020). Focusing on the liability side of the balance sheet, Foley-Fisher, Gorton, and Verani (2020) study investor reactions to the changes in information sensitivity of CLO securities, and Griffin and Nickerson (2020) assess the staleness of ratings of these securities. My paper contributes to this literature by explaining how the CLO contract design arises under financial frictions, governs the joint dynamics of intermediary assets and liabilities, and shapes the structure of the leveraged loan market.

More broadly, this paper’s analysis of nonbank intermediaries provides a new perspective on modern financial intermediation. Seminal work by Diamond and Dybvig (1983) and Gorton and Pennacchi (1990) find that by creating safe and liquid claims, intermediaries facilitate efficient allocation under information frictions. Subsequent research further develops the insight that safety creation drives intermediary asset choices (Hanson et al., 2015; DeAngelo and Stulz, 2015; Dang et al., 2017; Diamond, 2020; Drechsler, Savov, and Schnabl, 2021).<sup>6</sup> In the existing literature, there is no role for dynamic asset portfolios in the production of safe liabilities. The key innovation of my paper is to analyze how dynamic collateral management allows intermediaries to increase the supply of safe assets beyond the level produced by 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.

The normative analysis in this paper builds on insights from the theoretical literature on pecuniary externalities when agents face price-dependent borrowing constraints à la Shleifer and Vishny (1992) and Kiyotaki and Moore (1997). Under this financial friction, trades between heterogeneous agents may fail to achieve an efficient allocation because, through their

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<sup>6</sup>Empirical studies on the pricing of and the interactions among different safe assets include Krishnamurthy and Vissing-Jorgensen (2012), Sunderam (2015), Nagel (2016), Gissler and Narajabad (2018), and Infante (2020). Another strand of literature posits that an excessive production of private safe assets can lead to financial fragility due to fire sales (Stein, 2012; Greenwood, Hanson, and Stein, 2015) or neglected risks (Gennaioli, Shleifer, and Vishny, 2012, 2013).



influence on the binding constraints, competitive prices divert resources away from productive uses (e.g., [Caballero and Krishnamurthy, 2001](#); [Gromb and Vayanos, 2002](#); [Bianchi, 2011](#); [Bianchi and Mendoza, 2010](#); [Jeanne and Korinek, 2019](#)). [Dávila and Korinek \(2018\)](#) refer to this type of pecuniary externalities as “collateral externalities”. One strand of this literature studies how secondary market prices cause inefficiency when financial intermediaries trade loans. In [Stein \(2012\)](#), banks overborrow short-term safe debt against loan sales in bad times and do not internalize that lower loan prices inefficiently crowd out buyers’ other investments. [Neuhann \(2019\)](#) analyzes a setting where higher buyer wealth not only relaxes banks’ collateral constraints, but also compromises their incentives to screen loans, generating inefficiently low asset quality. To capture institutional features, my model substantially differs from this literature in two ways. First, safe debt is secured by substituting rather than liquidating risky loans, so collateral constraints are sensitive to the ratio, instead of the level, of loan prices. Second, intermediaries in my model have zero endowment and identical lending technology, and the direction of trades is flexibly determined by an intermediary’s financing choices. As a result, aggregate collateral depends on ex-ante lending by the two sides of the market, and equilibrium in this economy generally features underborrowing. This new form of inefficiency has important policy implications because traditional policies, if used in isolation, cannot restore constrained efficiency.

## 2 Motivating Evidence

Before presenting the theoretical framework, this section provides motivating evidence on the dynamic approach of safe asset production. Details on data and sample are in [Appendix C](#).

## 2.1 Institutional Background

Leveraged loans are private debt extended to corporations that have a high existing leverage.<sup>7</sup> These loans are originated through syndication deals, where underwriters (called “lead arrangers”) organize select groups of lenders to privately contract with the borrowers.<sup>8</sup> In recent years, the vast majority of leveraged loans are held by nonbanks.<sup>9</sup> Collateralized loan obligations (CLOs) are the largest group of nonbank intermediaries that invest in leveraged loans. Currently, the vast majority of CLOs are “open-market CLOs”, which are operated by asset managers that are independent from the underwriter banks.

The key feature of CLOs is active management. Unlike other securitized products that have static collateral portfolios, CLO managers can reinvest the cash flows generated by loan holdings during a predetermined reinvestment period. This allows the manager to both buy new loans in primary market and make discretionary secondary market trades. A CLO’s life lasts around 10 years, and the reinvestment period is typically the first 5 years. After the reinvestment period, the CLO enters its amortization period and repays its debt principals over time.<sup>10</sup> Manager compensation consists of fixed fees (based on tranche size) and incentive fees (based on equity performance).

**CLOs as Safe Asset Producers.** CLOs finance their lending by issuing debt and equity securities that have different seniorities in receiving cash flows.<sup>11</sup> Despite that leveraged loans have speculative-grade ratings, the most senior debt tranches (about 65% of liabilities)

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<sup>7</sup>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.

<sup>8</sup>Figure A.4 summarizes primary market relationships for underwriters and CLO asset managers between 2016–2019. Figure A.5 summarizes CLO participation in the primary market.

<sup>9</sup>Regulatory data (Shared National Credit Program) show that 84% of non-investment grade term loans are held by nonbanks in 2020.

<sup>10</sup>After the reinvestment period, CLOs cannot buy loans using the cash generated by discretionary loan sales or existing loans’ pre-scheduled payoffs (coupons and principals). But this does not prevent managers from using the cash generated by existing loans’ prepayments. See Fitch’s report for more details: [Reinvestment in Amortization Period of U.S. CLOs](#).

<sup>11</sup>The debt tranches have maturities between 6–12 years. Table 1 shows the distribution of CLO debt maturity by tranche seniority.

are rated AAA and have zero default record in history. These senior CLO securities are privately-produced safe assets by the definition in [Caballero, Farhi, and Gourinchas \(2017\)](#): they are debt instruments that are expected to preserve values during adverse systemic events. First, CLOs’ portfolios are well-diversified, typically consisting of 100–300 small pieces of loans. Second, the average default recovery rate of leveraged loans was around 75% in recent years.<sup>12</sup> Third, CLO contracts include covenants that protect debtholders, which will be introduced in detail in Subsection 2.2. These facts imply that the senior tranches are extremely unlikely to default.<sup>13</sup> Moreover, CLO debt tranches are floating rate notes, which protects investors from interest rate risk.

**Other Intermediaries.** In addition to CLOs, other nonbank intermediaries also hold hundreds of billions of leveraged loans.<sup>14</sup> These intermediaries, including mutual funds, hedge funds, pension funds, and private equity funds, do not issue any safe securities backed by their leveraged loan holdings. Lending in the same market requires similar skills, so asset managers should be able to choose which type(s) of intermediaries to operate. Consistent with this conjecture, Figure 2 shows that asset managers participate in the leveraged loan market by selectively operating CLOs and/or mutual funds. For example, CVC Credit Partners only offers CLOs, whereas Fidelity Investments predominantly manages leveraged loan mutual funds. Such financing choices lead to a coexistence of intermediaries with two distinct types of capital structures.

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<sup>12</sup>Corporate loans are senior to bonds and usually explicitly secured by collateral. See S&P report for more details on recovery rates: [LossStats](#).

<sup>13</sup>See SEC report ([Kothari et al., 2020](#), p.41–p.49) for related discussion on why given the COVID-19 crisis, CLO “AAA-rated senior tranches will not incur losses unless economic conditions worsen dramatically”.

<sup>14</sup>Figure A.3 in the Appendix provides more information on the size of different intermediary types in this market based on alternative data sources.

## 2.2 Contracts and Collateral Constraints

Leveraged loans and the borrowers are large: the average loan size is around \$700 million in my sample. This size creates an economy of scale in information production, and almost every single loan is rated by third parties. The availability of continually updated loan ratings allows CLO managers to commit to long-term contracts that discipline their future portfolio choices and collateral quality. CLO contracts implement this commitment with regular (e.g., monthly) collateral tests. In each period, test scores are calculated based on current loan holdings and compared with predetermined threshold levels. A test failure prevents the manager from receiving compensation until test scores recover.

The most important collateral test is the over-collateralization (OC) test.<sup>15</sup> The OC score for AAA tranches is calculated as

$$\text{AAA OC score} = \frac{\text{quality-adjusted total face value of loan holdings}}{\text{face value of AAA tranche outstanding}}, \quad (1)$$

where the quality adjustment is based on portfolio loans' current ratings and prices. When the OC test fails, covenants typically require the manager to accelerate debt repayment, which reduces the score's denominator.<sup>16</sup> However, an alternative action that also improves the OC score is increasing the numerator via secondary market trades. Which action will managers choose is an empirical question, and the answer is in the next subsection.

Collateral tests impose constraints that dynamically govern the relationship between a CLO's loan portfolio and safe debt capacity. Figure 3 presents quarterly cross-sectional distribution for the slackness of senior OC constraints between 2010–2019. Among CLOs in reinvestment period, the average OC score is only slightly (8%) above the minimum

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<sup>15</sup>Other collateral tests include the interest coverage (IC) test and interest diversion (ID) test, which also induce the manager to hold enough collateral for debt tranches.

<sup>16</sup>The repayment is achieved by diverting cash flows generated by loan holdings away from paying junior tranches (or buying more loans) to paying the senior tranche.

required level and is fairly stable over time.<sup>17</sup> In every quarter, the slackness of collateral constraints is tightly distributed around this average. These binding constraints have two interpretations: First, managers fully exploit safe debt capacity allowed by portfolios, and second, they carefully maintain just enough quality-adjusted loan holdings given safe debt outstanding. By contrast, constraint slackness is much larger on average and more dispersed for CLOs in amortization period. This is because CLO leverage decreases along with debt principal repayment, and their managers no longer actively trade loans.

## 2.3 Balance Sheet Dynamics around the Onset of COVID-19

Safe debt produced by CLOs are long-term bonds. This is different from traditional banking, where safe debt have very short maturities, and depositors can force intermediaries to pay back before asset losses fully materialize. Without short maturities to enforce repayment, do asset managers respond to negative macro shocks? Figure 4 depicts CLO balance sheet dynamics before and around the onset of COVID-19 crisis in 2020.

Panel (a) shows quarterly average total loan holdings, by CLO issuance year cohort. For all cohorts, portfolio size remained stable over time. This suggests that CLOs did not liquidate loans when the pandemic hit the economy. By contrast, Panel (b) shows that the pattern of early senior debt repayment dropped. While earlier cohorts on average repaid some of senior tranches after typically 2–3 years of non-call periods, such early repayment largely discontinued due to the difficulty of refinancing in 2020.

The absence of portfolio liquidation and early debt repayment does not imply that CLO managers did respond to the shock. In Panel (c), the average numbers of loan purchases and sales both nearly doubled upon the arrival of the COVID-19, which indicates that managers were actively buying and selling loans in the secondary market. To understand the nature

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<sup>17</sup>The observed senior OC thresholds are not necessarily that of the most senior (AAA) tranche, so my calculation over-states the actual slackness. See Appendix C.2 for details on this data limitation.

of these trades, Panel (d) examines loan trades within individual CLOs during the first two quarters of 2020. As the bin scatter plot shows, there is a strong positive (and nearly one-to-one) relationship between a CLO’s loan purchases and sales. Therefore, secondary market trades achieved portfolio substitution at the individual CLO level.

## 2.4 Portfolio Substitution Improves Collateral Quality

COVID-19 caused unanticipated and systematic deterioration of leveraged loan quality, which threatened CLOs’ binding collateral constraints. The previous subsection documents that managers responded to this threat by changing portfolio composition instead of repaying debt. This subsection uses granular CLO portfolio holdings data to examine how secondary market trades affect collateral quality.

Figure 5 presents portfolio changes from February 15 (“pre”) to June 30 (“post”) of year 2020, for all CLOs in reinvestment period (87% of the sample). Panel (a) shows OC constraint slackness before and after the shock.<sup>18</sup> As the pandemic caused a massive downgrading wave, the distribution of slackness shifts to the left, and the dispersion among CLOs increases. However, when the crisis settled in July, only 1.2% of CLOs failed senior OC tests.

The reason behind limited test failure, as the previous subsection suggests, could be portfolio substitution during the shock. To quantify its causal effect, for each CLO, I track individual loan quality changes and measure the portfolio’s counterfactual ex-post quality in the absence of loan trades.<sup>19</sup> Panel (b) shows the distribution of value-weighted portfolio average ratings. A larger numeric rating corresponds to a better letter rating (see Table 2 for details). Clearly, the pandemic lowered overall ratings, but managers’ trading mitigated deterioration, improving the realized ex-post distribution relative to the counterfactual.

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<sup>18</sup>I calculate constraint slackness using test scores reported by trustee banks. However, I am not able to calculate a counterfactual test score due to data limitations, such as unobservable cash holdings.

<sup>19</sup>See Subsection C.3 in the Appendix for details on the construction of counterfactual portfolios.

Although CLOs faced similarly binding constraints, their portfolios had different exposures to COVID-19. CLOs experiencing more severe deterioration would be forced to respond more intensively. I measure a CLO’s exposure with the difference in average rating between the pre and counterfactual-post portfolios.<sup>20</sup> Panel (c) shows that almost all CLOs replaced deteriorated loans, and that the effect on quality linearly increases in exposure. The slope estimate indicates that on average, portfolio substitution offsets 60% of quality deterioration caused by COVID-19. Panel (d) replaces the outcome variable with value-weighted average coupon rate, which measures portfolio quality based on primary market loan pricing. In response to a 1-notch decrease in average rating, the manager’s trades reduced portfolio average coupon by 30 basis points, or roughly one standard deviation.

Panels (e) and (f) examine the direction of loan trades by comparing ratings and coupons between the loans bought and sold by a CLO, respectively. Clearly, CLOs more threatened by the shock responded more aggressively in replacing low-quality loans. The results further support that binding collateral constraints triggered portfolio substitution trades that substantially improved collateral quality.

## 2.5 CLO Loan Trades and Secondary Market Prices

More than a thousand CLOs’ portfolio substitution trades in the same direction are likely to affect secondary market loan prices. This subsection examines the cross section of leveraged loan price drops in late March of 2020 (“mid” period), the epicenter of the COVID-19 shock. For each loan, I measure its transitory price drop as

$$Drop_j = \frac{Price_j^{mid}}{\frac{1}{2} \times (Price_j^{pre} + Price_j^{post})} - 1, \quad (2)$$

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<sup>20</sup>Figure A.6 in the Appendix shows a strong correlation between this counterfactual quality deterioration and ex-ante portfolio weight in pandemic-vulnerable industries.

where the prices are calculated using market values reported in CLO portfolio snapshots in the three periods.<sup>21</sup> This measure captures the magnitude of a loan’s price drop relative to a hypothetical linearly-extrapolated price level. My goal is to detect price pressures of CLO trades by comparing price drops across loans of different quality. To do so, I group individual loans based on rating and calculate an average drop magnitude for each group.

Empirically isolating loan price changes caused by CLO trades is challenging. To alleviate the concern that observed price changes could be merely driven by changes in perceived fundamentals, I also apply the same exercise above to high-yield bonds, which are not traded by CLOs, using similar data from mutual fund portfolio snapshots.

Figure 6 presents the results. Although all risky corporate debt experienced sizable transitory price drops, leveraged loans and high-yield bonds exhibited different cross-sectional patterns. In Panel (a), the magnitude of loan price drops is monotonic in credit rating, ranging from nearly 15% for the “B-” group to only 5% for the “BB+” group. By contrast, in Panel (b), the magnitudes of bond price drops are mostly around 15% across rating groups. These price patterns provide suggestive evidence that CLOs’ purchases (sales) of high-quality (low-quality) loans increase (decrease) secondary market loan prices. Such asymmetric price pressures makes it costly to improve collateral quality through trading.

### 3 A Model of Market-Based Safety Transformation

This section develops a model of safe asset production where intermediaries can credibly promise to dynamically maintain collateral quality through secondary market trading. To this end, the setup considers long-term contracts under full commitment and relegates the analysis of maturity choice and contractual frictions to Section 6.

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<sup>21</sup>I use market values reported in portfolio holdings because these prices are based on dealer quotes and trustee banks’ estimates, which help mitigate the concern of price staleness for infrequently traded debt. See Appendix C.1 for details on price measurement.



### 3.1 Environment

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

*Households.* In the beginning of period  $t = 0$ , a unit mass of risk-neutral households receive an endowment  $e$  of perishable consumption goods. In addition to consuming goods, households derive a non-pecuniary benefit  $\gamma$  from holding every unit of riskless financial claims that pay goods at  $t = 2$ . This benefit captures the convenience services provided by safe assets.<sup>22</sup> Households' utility is additively separable in consumption and convenience:

$$U = C_0 + \mathbb{E}_0[C_1 + C_2] + \gamma A, \quad (3)$$

where  $C_t$  is consumption in period  $t$ , and  $A$  is the aggregate quantity of safe assets available in period  $t = 0$ .<sup>23</sup>

A key friction in this economy is that financial markets are incomplete: households cannot create or trade claims contingent on states at  $t = 2$ . For this reason, in the absence of intermediaries, the supply of safe assets is zero. Households take securities prices as given when making investment and consumption decisions. I assume  $e$  to be sufficiently large, so the nonnegativity constraint in household investment problem is never binding.

*Intermediaries.* There is a continuum of asset managers uniformly populated on  $\mathcal{I} = [0, 1]$ . Their preference is the same as (3), except for that they do not benefit from holding safe assets. Each manager, indexed by  $i \in \mathcal{I}$ , operates an intermediary that has zero capital and issues securities to finance its risky investment. Intermediaries flexibly choose to issue any debt and equity securities. In particular, debt is safe if the portfolio's payoff at  $t = 2$  is always enough for repayment. By issuing such debt, intermediaries produce safe assets.

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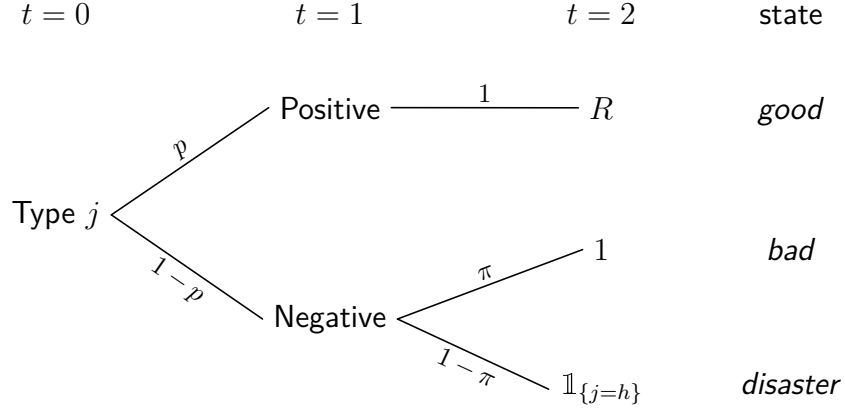
<sup>22</sup>One interpretation consistent with the CLO market is that AAA-rated securities help regulated institutions satisfy risk-based capital requirements.

<sup>23</sup>Similar utility functions are used in the literature to generate the demand for safe assets (e.g., [Krishnamurthy and Vissing-Jorgensen, 2012](#); [Stein, 2012](#); [Diamond, 2020](#)).

Managers can credibly commit to future portfolio choices and repayment.

Asset managers are ex ante identical on the asset side. On the liability side, issuing safe debt incurs a variable cost  $\xi_i \geq 0$ , which may differ across managers. Consistent with recent empirical evidence, this cost captures managers' tranching skill, i.e., the expertise in securitization and raising capital from investors with different risk-bearing capacities.<sup>24</sup>

*Investment Technology.* Asset managers have access to two types ( $h$  and  $l$ ) of scalable real projects. Every unit of investment in a project generates a gross payoff that depends on state  $\omega \in \Omega = \{g, b, d\}$  at  $t = 2$ . In period  $t = 1$ , a piece of public news arrives, which can be either positive or negative with probabilities  $p$  and  $1 - p$ , respectively. If the news is positive, state  $g$  (“good”) will realize with certainty, and both types of projects' payoffs will be  $R > 1$ . If the news is negative, whether the state is  $b$  or  $d$  remains uncertain. With probability  $\pi \in (0, 1)$ , state  $b$  (“bad”) will realize, and the two types both pay one unit of consumption goods. With probability  $1 - \pi$ , state  $d$  (“disaster”) realizes. While project  $h$  still pays 1 in this state, project  $l$  pays zero.



The tree graph illustrates project payoff distributions: the two types only differ in the payoff in state  $d$ . Operating projects at scale  $x$  incurs cost  $c(x)$ , where  $c$  is increasing, twice

<sup>24</sup>Cordell, Roberts, and Schwert (2021) show that on average CLO managers do not exhibit skill in selecting loans relative to other market participants, but they earn economic rents from issuing highly rated tranches.

differentiable, and strictly convex, and satisfies  $c(0) = 0$ . This convex cost captures the limited lending opportunities faced by individual managers in the private debt market. Project payoffs are fully pledgeable, and asset managers enjoy full bargaining power.<sup>25</sup> By providing capital to projects, an intermediary originates risky loans.<sup>26</sup> Depending on project types, I refer to the loans as high-quality ( $h$ ) and low-quality ( $l$ ) loans, respectively.

*Financial Markets.* Households can only invest through intermediaries, who originate risky loans and issue securities in period  $t = 0$ . Events in this period occur in the following order. Each intermediary  $i \in \mathcal{I}$  originates  $x_i$  units of loans without knowing their types. Immediately after origination, an idiosyncratic quality shock exogenously determines loan types. Specifically,  $\tilde{x}_{i,l}$  units of loans become type  $l$ , and the remaining  $x_{i,h} = x_i - \tilde{x}_{i,l}$  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 quantity  $\tilde{x}_{i,l}$  is publicly observed, but which loans are low-quality is unknown in this period.

To finance the invested capital  $c(x_i)$ , the intermediary issues safe debt with face value  $a_i \geq 0$  and raises the remaining capital with external equity.<sup>27</sup> Here the equity securities can be also interpreted as other risky liabilities, such as junior debt. Since consumption goods are non-storable, intermediaries do not hold “cash”. After these choices, an intermediary’s balance sheet in period  $t = 0$  is:

In period  $t = 1$ , loan quality publicly reveals, and intermediaries can trade loans in a Walrasian secondary market. Let the two types of risky loans’ secondary market prices be

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<sup>25</sup>This assumption, following [Stein \(2012\)](#), abstracts away contractual frictions between intermediaries and firms and simplifies the welfare analysis. An intuitive interpretation of this assumption is that the borrowers’ operating income will be entirely paid to intermediaries as interest expense.

<sup>26</sup>In practice, underwriters (“lead arrangers”) 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](#)), I abstract away the underwriting process and refer to the nonbank lending activity as origination.

<sup>27</sup>The assumed order of events is consistent with industry practice: the manager acquires loans using short term-financing during the “warehouse phase” and then issues securities to repay the borrowed capital.

Assets	Liabilities
$x_{i,h}$ and $x_{i,l}$	safe debt: $a_i$
	external equity + internal equity

$(q_l, q_h) \in \mathbb{R}_+^2$ . In period  $t = 2$ , the macro state  $\omega$  realizes, and risky loans generate payoffs accordingly. Households receive payments from securities issued by intermediaries, and asset managers 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. In the negative-news stage in period  $t = 1$ , given the intermediary's balance sheet state  $(x_{i,h}, x_{i,l}, a_i)$ , manager  $i$  chooses net trades  $\Delta x_{i,h}, \Delta x_{i,l}$  to maximize conditional expected payoff to equity

$$v^{neg}(x_{i,h}, x_{i,l}, a_i) = \max_{\Delta x_{i,h}, \Delta x_{i,l}} x_{i,h} + \Delta x_{i,h} + \pi(x_{i,l} + \Delta x_{i,l}) - a_i. \quad (\text{P1})$$

These trades are subject to a budget constraint

$$\sum_j (x_{i,j} + \Delta x_{i,j}) q_j \leq \sum_j x_{i,j} q_j, \quad (\text{BC})$$

a maintenance collateral constraint

$$a_i \leq x_{i,h} + \Delta x_{i,h}, \quad (\text{MCC})$$

and short-sale constraints  $\Delta x_{i,h} \geq -x_{i,h}, \Delta x_{i,l} \geq -x_{i,l}$ . The budget constraint (BC) requires the intermediary's trades to be self-financed by its loan portfolio. The maintenance collateral constraint (MCC) requires that after secondary market trades, safe debt investors receive the promised payoff with probability one.<sup>28</sup> This ensures that portfolio payoff always stays in the solvent region, which endogenously removes the nonlinearity in equity payoff.

Asset managers rationally anticipate trades in period  $t = 1$  when making balance sheet

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<sup>28</sup>For example, if initial holding of loan  $h$  is less than safe debt outstanding ( $x_{i,h} < a_i$ ), after observing negative news, the manager has to acquire additional high-quality loans to fulfill the commitment.

choices in period  $t = 0$ . Facing price-taking households, managers optimally price safe debt at  $1 + \gamma$  to extract all rents from safe asset production. So, by issuing one unit of safe debt, an intermediary effectively raises  $1 + \gamma - \xi_i$  units of capital. Taking loan prices  $(q_h, q_l)$  as given, the manager chooses investment  $x_i$  and safe debt issuance  $a_i$  to maximize expected payoff to internal equity

$$\max_{x_i, a_i \geq 0} \mathbb{E}_0[v(x_{i,h}, x_{i,l}, a_i)] - \underbrace{\left(c(x_i) - (1 + \gamma - \xi_i)a_i\right)}_{\text{cost of external equity}} \quad (\text{P0})$$

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

$$a_i q_h \leq x_{i,h} q_h + x_{i,l} q_l, \quad (\text{ICC})$$

which requires the portfolio's market value at  $t = 1$  to be enough for the manager to satisfy constraint (MCC) through loan trades.<sup>2930</sup>

*Equilibrium.* In equilibrium, secondary market trades and loan prices must be consistent with intermediary balance sheet choices; Meanwhile, balance sheets are chosen based on anticipated secondary market outcomes. Therefore, the equilibrium features an intertemporal feedback loop between primary and secondary markets.

**Definition 1** (Competitive Equilibrium). *An equilibrium consists of balance sheet choices  $(x_i, a_i)$  and secondary market trades  $(\Delta x_{i,h}, \Delta x_{i,l})$  for each manager and secondary market prices  $(q_h, q_l)$  such that (i) balance sheet choices solve the manager's investment and financing problem (P0) given  $(q_h, q_l)$ , (ii) secondary market trades solve the manager's trading problem (P1) given  $(q_h, q_l)$ , and (iii) secondary market clears:  $\int_{i \in \mathcal{I}} \Delta x_{i,j} = 0$  for  $j \in \{h, l\}$ .*

<sup>29</sup>Since loan  $h$  pays 1 even in the disaster state,  $a_i q_h$  is the minimum portfolio market value that allows the manager to achieve a minimum portfolio possible payoff  $a_i$ .

<sup>30</sup>Section 6 shows that it is without loss of generality to ignore the possibility of early debt repayment under the setup in the current section.

I impose two parametric assumptions to restrict the analysis to interesting cases. First, the safe debt issuance cost is sufficiently small. This assumption implies that any manager, regardless of its securitization expertise, can lower the cost of capital by issuing safe debt.

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

Second, I impose an inequality between the magnitude of quality shock and loan payoff.

**Assumption 2.** *The marginal cost of real investment at scale  $\bar{x}_l$  is bounded from above:*

$$c'(\bar{x}_l) < pR + 1 - p.$$

This inequality ensures that the manager's optimal choice  $x_i > \bar{x}_i$  for all  $i \in \mathcal{I}$ . Hence at the margin, the quality shock's realization is irrelevant to the manager's choice of investment quantity, and the sequential choices within period  $t = 0$  can be equivalently formulated as a simultaneous decision problem.<sup>31</sup>

*Discussion of the Setup.* The model builds on two primary assumptions. First, households benefit from safe assets. Because of this preference, safe debt can be priced at a premium, and capital structure is relevant to an intermediary's value, thus breaking the [Modigliani and Miller \(1958\)](#) theorem. Second, the investment technology exhibits decreasing returns to scale at the manager level, which is standard in the asset management literature and consistent with the fact that intermediary balance sheets are generally small relative to the size of the leveraged loan market. Another assumption is that managers are allowed to have different tranching skills. How this heterogeneity affects the equilibrium will be extensively discussed in [Section 4](#).

The key feature of this model is that secondary market trades can generate a higher minimum possible portfolio payoff than that of a static portfolio. This can occur because

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<sup>31</sup>The assumption of an exogenous upper-bounded quality shock simplifies the analysis but is not critical.

idiosyncratic quality shocks cause intermediaries to hold risky loans of different quality. Having two types of risky loans parsimoniously captures this effect. The assumed payoff distribution is not crucial but helps keep the mechanism transparent.<sup>32</sup>

### 3.2 Autarky

As a basic benchmark, consider the case where no secondary loan market exists. Let  $c'^{-1}(\cdot)$  be the inverse function of first-order derivative of the lending cost  $c$ . The lemma below summarises the investment and financing choices in this case.

**Lemma 1.** *In autarky, intermediary balance sheet choices satisfy  $x_i^{AUT} = c'^{-1}(pR + 1 - p + \gamma - \xi_i)$  and  $a_i^{AUT} = x_i^{AUT} - x_{i,l}$  for all  $i \in \mathcal{I}$ .*

*Proof.* See Appendix A. □

Without a secondary market, every intermediary issues safe debt, which is backed by its own high-quality loans. The size of an intermediary's balance sheet is increasing in the manager's securitization expertise. This market structure resembles traditional banking, where risky loans stay on banks' balance sheets, and deposit productivity drives bank size (Egan, Lewellen, and Sunderam, 2021).

### 3.3 Balance Sheets and Secondary Market Trades

This subsection characterizes managers' choices given loan prices. Since balance sheet choices depend on continuation value  $v$ , I begin with the secondary market problem in period  $t = 1$ .

In the positive-news stage, no trade occurs because all collateral constraints are slack. If negative news arrives, binding collateral constraints force managers to trade. The objective

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<sup>32</sup>Subsection 6.1 analyzes intermediaries' safe debt maturity choices in a setting with generalized conditional payoff distributions.

in problem (P1) strictly increases in both  $\Delta x_{i,h}$  and  $\Delta x_{i,l}$ , so the budget constraint binds:  $\Delta x_{i,h}q_h + \Delta x_{i,l}q_l = 0$ . Moreover, since  $a_i \geq 0$ , collateral constraint (MCC) implies that short-sale constraint  $\Delta x_{i,h} \geq -x_{i,h}$  is slack. Omitting terms predetermined at  $t = 1$ , the manager's secondary market problem simplifies to

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

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, each manager chooses the quantities of substitution between the two risky loan types through secondary market trades. Note that the arrival of negative news updates loan  $h$ 's and loan  $l$ 's fundamental values to 1 and  $\pi$ , 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 deviates from the ratio of fundamental values:  $\frac{q_l}{q_h} \in (0, \pi]$ .*

*Proof.* See Appendix A. □

While managers facing binding constraints are forced to acquire additional high-quality loans, managers facing slack constraints only care about returns. Since intermediaries trade among themselves, the market clears only if risky loans change hands between these two groups. Low-quality loans, which have zero collateral value in this state, must offer a higher expected return, so that unconstrained managers are willing to provide liquidity. As a result, the ratio of secondary market loan prices diverges from fundamental values.<sup>33</sup>

Lemma 2 indicates that the manager's optimal trades lead to portfolio substitution:

$$\Delta x_{i,h} = a_i - x_{i,h}, \quad \Delta x_{i,l} = -\frac{(a_i - x_{i,h})q_h}{q_l} \quad (4)$$

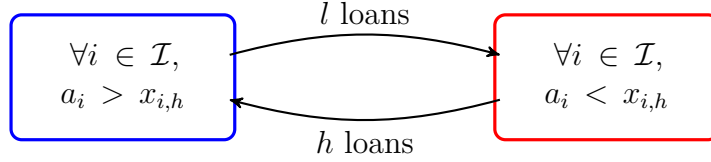
for any given  $x_{i,h}$  and  $a_i$ . As illustrated by the graph below, these trades reallocate risky

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<sup>33</sup>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 subsection.



loans among intermediaries. A manager with  $a_i > x_{i,h}$  optimally sells just enough low-quality loans to increase her holding of high-quality loans to keep debt safe. By contrast, a manager with  $a_i < x_{i,h}$  sells its extra high-quality loans and buys low-quality loans, thereby profiting from the deviation of loan prices from fundamentals. Driven by binding collateral constraints, the trading volume of high-quality loans is inelastic to prices.



The optimal trades in (4) imply that equity holders' continuation value in the negative-news stage is

$$v(x_{i,h}, x_{i,l}, a_i) = \pi \left( x_{i,l} + (x_{i,h} - a_i) \frac{q_h}{q_l} \right). \quad (5)$$

In equation (5), high-quality loans' payoff exceeds the fundamental:  $\pi \frac{q_h}{q_l} > 1$ . This is because holding high-quality loans reduces costly portfolio substitution if  $x_{i,h} < a_i$ , and extra high-quality loans can be sold for a higher return if  $x_{i,h} > a_i$ . Substitute  $v(x_{i,h}, x_{i,l}, a_i)$  into (P0), the manager's investment and financing problem is equivalent to<sup>34</sup>

$$\max_{x_i, a_i} p(x_i R - a_i) + (1-p)\pi \left( x_{i,l} + (x_i - x_{i,l} - a_i) \frac{q_h}{q_l} \right) - (c(x_i) - (1+\gamma - \xi_i)a_i) \quad (\text{P0a})$$

$$s.t. \ a_i \leq x_i - x_{i,l} + x_{i,l} \frac{q_l}{q_h}, \quad (\text{ICCa})$$

$$a_i \geq 0.$$

Let  $\eta_i$  and  $\mu_i$  respectively be the Lagrangian multipliers of the two constraints above. The manager's Kuhn-Tucker conditions for optimal choices are

$$pR + (1-p)\pi \frac{q_h}{q_l} - c'(x_i) + \eta_i = 0, \quad (6)$$

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<sup>34</sup>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.

$$\gamma - \xi_i - (1 - p)\left(\pi \frac{q_h}{q_l} - 1\right) - \eta_i + \mu_i = 0, \quad (7)$$

and

$$\eta_i \geq 0, \eta_i \left( a_i - \left( x_{i,h} + x_{i,l} \frac{q_l}{q_h} \right) \right) = 0, \mu_i \geq 0, \mu_i a_i = 0. \quad (8)$$

Equation (7) states that a manager's financing choice depends on a tradeoff between safe debt's net cheap financing,  $\gamma - \xi_i$ , and expected cost of trading,  $(1 - p)\left(\pi \frac{q_h}{q_l} - 1\right)$ . If the former is less than the latter, no safe debt would be issued ( $\mu_i > 0$ ), and the collateral constraint would be slack ( $\eta_i = 0$ ). In this case, investment choice in (6) is simply based on a tradeoff between expected payoff of lending and the marginal cost of origination.

Instead, if the benefit of safe debt financing exceeds expected cost of trading, collateral constraint (ICCa) binds, with shadow price

$$\eta_i = \gamma - \xi_i - (1 - p)\left(\pi \frac{q_h}{q_l} - 1\right) > 0. \quad (9)$$

On the liability side, the manager chooses to fully exhaust safe debt capacity,  $a_i = x_{i,h} + x_{i,l} \frac{q_l}{q_h}$ , to exploit cheap financing. On the asset side, as characterized by equation (6), investment choice exceeds what the payoff-cost tradeoff suggests. The additional investment is driven by the collateral value of risky loans. As  $\eta_i$  decreases in  $\xi_i$ , a manager with better securitization expertise originates more loans as collateral to issue more safe debt.

### 3.4 Social Planner's Problem

In this subsection, I consider a benevolent social planner who organizes intermediaries to efficiently make risky investments and produce safe assets. Similar to the decentralized economy, secondary market trading can improve safe debt capacity. But unlike asset managers, the planner does not calculate individual payoffs taking as given the secondary market prices. By internalizing the impact of his choices on prices, the planner can potentially improve the

economy's total welfare.

Specifically, the planner controls intermediaries' investment and financing choices at  $t = 0$  and lets asset managers trade without any intervention at  $t = 1$ . In the negative-news stage, binding collateral constraints trigger loan trades, same as in equation (4). The secondary market can clear if and only if  $\int_{i \in \mathcal{I}} (a_i - x_{i,h}) di \leq 0$ , which gives rise to an aggregate collateral constraint faced by the social planner.<sup>35</sup>

To establish a sensible welfare benchmark, I do not allow the planner to freely redistribute loans among intermediaries in period  $t = 1$ . So for the promised trades to be feasible, the same initial collateral constraint (ICCa) in the decentralized economy,  $a_i \leq x_{i,h} + x_{i,l} \frac{q_l}{q_h}$ , must be satisfied for every intermediary. Recognize that the slackness of these constraints strictly increases in price ratio  $\frac{q_l}{q_h}$ , and that loan prices do not affect the planner's objective or any other constraint (see the formalized problem below). Therefore, a higher price ratio at least weakly improves the maximized total surplus, and the planner implements the highest price ratio that clears the market:  $\frac{q_l}{q_h} = \pi$ .

The planner's optimization problem is as follows. Let total investment be  $X = \int_0^1 x_i di$ . By law of large numbers, aggregate low-quality loan is  $\int_0^1 \tilde{x}_{i,l} di = x_L$ . Since all investment payoffs will be consumed by households and asset managers, the planner's objective is to maximize the sum of investment payoffs and safe asset non-pecuniary benefits, minus the aggregate costs of investment and safe debt issuance:

$$\max_{\{x_i, a_i\}_{i \in \mathcal{I}}} pXR + (1-p)(X - x_L + \pi x_L) + \gamma A - \int_{i \in \mathcal{I}} (c(x_i) + \xi_i a_i) di \quad (\text{SP})$$

$$s.t. \quad A \leq X - x_L, \quad (\text{ACC})$$

$$a_i \leq x_i - x_{i,l} + x_{i,l} \pi, \quad \forall i \in \mathcal{I}, \quad (\text{ICC})$$

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

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<sup>35</sup>The market clears when the inequality is strict if  $\frac{q_l}{q_h} = \pi$ , a special case in which unconstrained managers are indifferent between the two types of loans and thus do not attempt to replace their entire holdings of loan  $h$  with loan  $l$  in the secondary market.

The Lagrangian for problem (SP) can be written as

$$\begin{aligned}\mathcal{L}^{SP} = & pXR + (1-p)(X - x_L + \pi x_L) + \gamma A - \int_{i \in \mathcal{I}} (c(x_i) + \xi_i a_i) di \\ & - \psi^{SP}(A - (X - x_L)) - \int_0^1 \eta_i^{SP}(a_i - x_{i,h} - x_{i,l}\pi) di + \int_0^1 \mu_i^{SP} a_i di.\end{aligned}\tag{10}$$

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

$$pR + 1 - p - c'(x_i) + \psi^{SP} + \eta_i^{SP} = 0,\tag{11}$$

$$\gamma - \xi_i - \psi^{SP} - \eta_i^{SP} + \mu_i^{SP} = 0,\tag{12}$$

and

$$\eta_i^{SP} \geq 0, \eta_i^{SP}(a_i - x_{i,h} - x_{i,l}\pi) = 0, \mu_i^{SP} \geq 0, \mu_i^{SP} a_i = 0.\tag{13}$$

The differences in the tradeoffs behind individual managers' and the planner's choices can be seen from comparing first-order conditions (6)–(7) and (11)–(12). The planner's choice of an intermediary's lending, as characterized by (11), accounts for both individual ( $\eta_i^{SP}$ ) and social ( $\psi^{SP}$ ) collateral values. This social collateral concept reflects the consideration that high-quality loans provide value to not just the lender itself, as these loans can be reallocated to other intermediaries to protect safe debt in bad times. For financing choices characterized by (12), the planner trades off between the net benefit from producing safe asset and the reduction in social safe debt capacity, instead of a private cost of contingent secondary market trading.

## 4 Equilibrium and Welfare

This subsection characterizes the equilibrium and analyzes its welfare properties. In the equilibrium's feedback loop, a key metric that links managers' intertemporal choices is price ratio  $\frac{q_l}{q_h}$ . This ratio captures the rate of substitution between risky loans. When it is higher,

replacing deteriorated loans is less costly, and providing liquidity is less profitable, so safe debt financing is more attractive. However, safe debt issuance increases the demand (supply) for high-quality (low-quality) loans, and the market cannot clear unless the price ratio drops sufficiently. To be an equilibrium, loan prices must adjust and equalize secondary market demand and supply.

Therefore, dynamic collateral management generates a *pecuniary externality*: trades move loan prices, which in turn affect the constraints faced by all managers. Managers take loan prices as given when maximizing their own payoffs and do not internalize this externality.

The market-clearing condition  $\int_i \Delta x_{i,j} di = 0$  and optimal trades in (4) jointly imply an equilibrium relationship that is consistent with Walras law. That is, aggregate safe debt must equal aggregate high-quality loans in the economy:

$$\int_{i \in \mathcal{I}} a_i di = \int_{i \in \mathcal{I}} x_{i,h} di. \quad (14)$$

Equation (14) arises from the fact that only high-quality loans, which pay off even in the disaster state, are the ultimate collateral that secures safe debt. In aggregate, the intermediary sector's total holding of high-quality loans equals total safe debt outstanding, so that the secondary market demand for collateral equals the supply.

This relationship also holds in the planned economy. To see this, note that in the planner's problem (SP), the aggregate collateral constraint (ACC) binds at the optimum: otherwise, there would be some  $i \in \mathcal{I}$  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. Intuitively, aggregate high-quality loans determine social safe debt capacity, and it is optimal to fully exhaust this capacity. This observation will be useful for understanding equilibrium allocations.

## 4.1 Special Case: Homogeneous Managers

While managers are ex ante identical on the asset side, the difference in their securitization expertise may lead to different balance sheet choices and equilibrium outcomes. As a benchmark, consider a homogeneous case:  $\xi_i = \xi^* \in [0, \gamma)$  for all  $i \in \mathcal{I}$ . Hence, all managers are completely identical ex ante. The following lemma presents the set of competitive equilibria in this case.

**Lemma 3.** *If managers are homogeneous,  $\frac{q_l}{q_h} = \frac{(1-p)\pi}{1-p+\gamma-\xi^*}$ ,  $x_i = c'^{-1}(pR + 1 - p + \gamma - \xi^*)$ , 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 (14) is an equilibrium. The market produces the same quantity of safe assets as in autarky, and every competitive allocation is constrained efficient.*

*Proof.* See Appendix A. □

When managers are homogenous, secondary market prices adjust until everyone is indifferent about financing choices, and all collateral constraints slack. That is, the benefit of issuing one more unit of safe debt will equal the profit of selling one more unit of collateral to others. This indifference implies that lending choices, as well as the overall supply of safe assets, coincide with the case where nobody sells collateral to others, namely, autarky (Lemma 1). The equilibrium is unique up to aggregate quantities, but there are infinite possible combinations of individual choices, which generate different individual secondary market trades.

In this case, the planner cannot do better than the competitive market. This is because the planner also faces slack individual collateral constraints and is indifferent about which manager issues more or less safe debt given that all managers are equally skilled at tranching. Although the pecuniary externality shrinks the set of competitive equilibria, it does not affect the efficiency of allocation.

## 4.2 Equilibrium with Continuous Manager Types

Having a secondary market does not add any economic value if managers are homogenous. Then why do we observe dynamic collateral management in practice? Similar to the heterogeneity in deposit productivity across banks, asset managers may have different expertise in raising capital from investors with different risk-bearing capacities. My equilibrium analysis mainly focuses on a case where every manager's securitization expertise is different from others'. This case allows for a clean characterization that generates intuition similar to the cases with discrete types, for which I provide an analysis in Appendix B.

Without loss of generality, let manager  $i$ 's variable safe debt issuance cost be  $\xi_i = 2\xi i$  for constant  $\xi \in (0, \gamma/2)$ . Thus, managers are ranked by issuance cost, which is uniformly distributed on  $[0, 2\xi]$ . Under this heterogeneity, equation (7) indicates that the constraints on safe debt choices bind for almost everyone. A manager with a higher issuance cost benefits less from safe debt financing and is more willing to issue only equity. Hence, financing choices at the extensive margin can be summarized by a cutoff  $\lambda \in [0, 1]$ : managers  $i \leq \lambda$  issue both safe debt and equity, and managers  $i > \lambda$  issue only equity. In equilibrium, the price ratio makes the cutoff type  $\lambda$  indifferent between issuing safe debt and providing liquidity in the secondary market:

$$\gamma - \xi_\lambda = (1 - p) \left( \pi \frac{q_h}{q_l} - 1 \right). \quad (15)$$

In the appendix, I show that the system of two equations, the indifferent cutoff condition and the market-clearing condition, is equivalent to a single equation  $\chi(\lambda) = 0$  for aggregate excess demand function  $\chi : [0, 1] \mapsto \mathbb{R}$ , and that this equation has a unique real root. The planner faces similar tradeoffs, so his choices also feature a cutoff. The following proposition characterizes the competitive and planned allocations.<sup>36</sup>

**Proposition 1** (Cutoff Allocations). *There exists a unique competitive equilibrium. In*

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<sup>36</sup>Here the uniqueness is with respect to the quantities of choices and the price ratio. The levels of loan prices are not uniquely identified. Subsection 6.1 generalizes the setting to allow for identified price levels.

equilibrium, there is an interior cutoff  $\lambda^{CE} \in (0, 1)$  such that

$$x_i^{CE} = \begin{cases} c'^{-1}(pR + 1 - p + \gamma - \xi_i), & \text{if } i \leq \lambda^{CE} \\ c'^{-1}(pR + 1 - p + \gamma - \xi_{\lambda^{CE}}), & \text{if } i > \lambda^{CE} \end{cases}, \quad (16)$$

$$a_i^{CE} = \begin{cases} x_i^{CE} - x_{i,l} + x_{i,l} \frac{q_l}{q_h}, & \text{if } i \leq \lambda^{CE} \\ 0, & \text{if } i > \lambda^{CE} \end{cases}, \quad (17)$$

and

$$\frac{q_l}{q_h} = \frac{(1-p)\pi}{1-p+\gamma-\xi_{\lambda^{CE}}} < \pi. \quad (18)$$

The social planner's choices lead to  $\frac{q_l}{q_h} = \pi$  and a unique interior cutoff  $\lambda^{SP} \in (0, 1)$  such that

$$x_i^{SP} = \begin{cases} c'^{-1}(pR + 1 - p + \gamma - \xi_i), & \text{if } i \leq \lambda^{SP} \\ c'^{-1}(pR + 1 - p + \gamma - \xi_{\lambda^{SP}}), & \text{if } i > \lambda^{SP} \end{cases}, \quad (19)$$

$$a_i^{SP} = \begin{cases} x_i^{SP} - x_{i,l} + x_{i,l}\pi, & \text{if } i \leq \lambda^{SP} \\ 0, & \text{if } i > \lambda^{SP} \end{cases}. \quad (20)$$

*Proof.* See Appendix A. □

An important feature of this market equilibrium is that intermediary financing choices are qualitatively different: “CLOs” and “mutual funds” endogenously coexist and trade as counterparties in the secondary market. CLO managers optimally exhaust their safe debt capacity by promising to replace the entirety of deteriorated loans after seeing negative news.<sup>37</sup> This promise maximizes ex-ante cheap leverage and allows the managers to enjoy high payoffs after positive news. By contrast, mutual fund managers give up safe debt's cheap funding advantage and profit from providing liquidity to CLOs.

Figure 7 numerically illustrates the equilibrium. In Panel (a), the range of the price ratio

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<sup>37</sup>To see this, substitute the safe debt choice (17) into optimal trades in (4).



is divided into three regions. If the price ratio is too low, no manager would issue safe debt ( $\lambda = 0$ ), and secondary market demand for high-quality loans would be zero. If the price ratio is too high, all managers would issue safe debt ( $\lambda = 1$ ), and secondary market supply for high-quality loans would be zero. Only when the price ratio is in the medium region, a proper subset of intermediaries issue safe debt ( $0 < \lambda < 1$ ), and secondary market clears.

Panel (b) presents the cross section of balance sheet choices in equilibrium and compare them with autarky. In equilibrium, the market has an interior mix of intermediaries with two distinct capital structures. Overall, intermediaries operated by managers with lower issuance costs tend to issue more safe debt and have bigger balance sheet sizes. This market structure increases the supply of safe assets relative to autarky because the anticipation of ex-post trades increases the total quantity of collateral ex ante. Such a benefit from market-based safety transformation can be seen from the wedge between  $x_i^{CE}$  and  $x_i^{AUT}$ .

**Corollary 1.1.** *The competitive equilibrium produces more safe assets than in autarky ( $A^{CE} > A^{AUT}$ ) because managers less skilled at securitization ( $i > \lambda^{CE}$ ) originate more high-quality loans, which are sold in the secondary market in bad times.*

The planner's allocation also divides managers into operating CLOs and operating mutual funds. Cutoff  $\lambda^{SP}$  reflects the socially optimal concentration of safe asset production. As this cutoff is generally different from  $\lambda^{CE}$ , the planned allocation differs from competitive allocation in terms of both assets and liabilities, suggesting that the unique competitive equilibrium is constrained inefficient. The next proposition characterizes the inefficiency of the competitive equilibrium.

**Proposition 2** (Constrained Inefficiency). *The equilibrium is constrained inefficient: the market has an excessively large share of safe debt-financed intermediaries ( $\lambda^{CE} > \lambda^{SP}$ ) but under-produces safe assets ( $A^{CE} < A^{SP}$ ).*

*Proof.* See Appendix A. □

Since the financial markets are incomplete, an intermediary's trades affect not only other intermediaries' secondary market budget constraints, but also their collateral constraints. As collateral constraints are binding for CLOs, the effect on these constraints compromises the standard envelope-theorem argument for welfare irrelevance of prices in complete markets. By internalizing the price impact of intermediary balance sheet choices, the planner is able to implement a price ratio that is unsustainable in the competitive market. A higher price ratio relaxes collateral constraints for all intermediaries, thereby allowing the planner to efficiently organize investment and financing.

**Corollary 2.1.** *Equity-financed intermediaries' private profits from trading are lower than the social benefit of collateral.*

On the asset side, managers underinvest whenever they do not issue the socially-efficient quantities of safe debt. Facing a decreasing returns to scale in investment, the planner optimally spreads lending among all managers. He does so by forcing managers with inferior securitization expertise to invest beyond their privately-optimal quantities. In the competitive market, managers' investment choices limit secondary market supply of high-quality loans and cause a deficiency of aggregate collateral.

**Corollary 2.2.** *For intermediaries with medium securitization expertise:  $i \in (\lambda^{SP}, \lambda^{CE})$ , issuing safe debt is privately optimal but socially suboptimal.*

On the liability side, safe debt issuance by managers with less securitization expertise crowds out efficient issuance by other managers. This occurs as the former group's promised trades reduce collateral that can be acquired by the latter group in bad times. 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 many intermediaries issue safe debt, and the market underproduces safe assets at a high average cost.

Figure 8 overlays the competitive allocation and the planned allocation. The planner assigns only 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 originate more than their competitive levels:  $x_i^{SP} > x_i^{CE}$ .<sup>38</sup> The area of the shaded region measures aggregate underinvestment in equilibrium, which equals the quantity of safe asset underproduction.

## 5 Policy Intervention

The previous section shows that the market has excessively many intermediaries that use safe debt financing. Consider a policy that imposes an entry cost on asset managers who operate safe debt-financed intermediaries. By negatively affecting these managers' payoff, this policy potentially deters entry into safe debt issuance and improves welfare. This section explores how such a policy impacts equilibrium outcomes.

Suppose that if intermediary  $i$  issues safe debt of any quantity  $a_i > 0$ , the manager incurs a cost  $\zeta_i \in \mathbb{R}_+$  in the beginning of period  $t = 0$ .<sup>39</sup> For generality, the cost can be an arbitrary (weakly) increasing function of index  $i \in \mathcal{I}$ . This assumption allows for any monotonic heterogeneity in the policy's impact: it's possible that a less resourceful manager (i.e., having a higher safe debt issuance cost  $\zeta_i$ ) also faces a higher policy-induced entry cost.

Under this policy, the manager's  $t = 0$  optimization problem becomes discontinuous. The discontinuity at  $a_i = 0$  is because issuing any safe debt incurs the manager the entry cost  $\zeta_i$ . Conditional on a binary choice between  $a_i = 0$  and  $a_i > 0$ , the objective function is the same as (P0a). Given loan prices and the same collateral constraint (ICCa), *locally optimal*

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<sup>38</sup>For managers in  $[0, \lambda^{SP}]$ , individually and socially optimal choices of origination coincide, because they directly benefit from, and hence fully internalize, the collateral value of risky loans.

<sup>39</sup>This timing convention is for simplicity: the financing choice does not depend on the realization of idiosyncratic loan quality shocks.

choices are characterized by the same conditions (6)–(8) as in the baseline model.

The policy distorts asset managers' safe debt issuance choices, which in turn affect their investment choices. If an intermediary issues only equity, the manager's payoff is

$$V^e = y^e c'^{-1}(y^e) - c(c'^{-1}(y^e)) - (1-p)\pi x_L \left( \frac{q_h}{q_l} - 1 \right), \quad (21)$$

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

$$V_i^d = y_i^d c'^{-1}(y_i^d) - c(c'^{-1}(y_i^d)) - (1-p)\pi x_L \left( \frac{q_h}{q_l} - 1 \right) - x_L \eta_i \left( 1 - \frac{q_l}{q_h} \right) - \zeta_i, \quad (22)$$

where  $y_i^d := y^e + \eta_i$  is the manager's marginal payoff from originating risky loans, which includes collateral value  $\eta_i$ . Note that  $V_i^d$  is strictly increasing in  $\eta_i$ , which itself decreases in manager index.<sup>40</sup> This implies that  $V_i^d$  is strictly larger for a smaller  $i$ . Since  $V^e$  is identical across  $i$ , others equal, only managers better at securitizing might issue safe debt.

To be consistent with the baseline model, I use  $\lambda$  to denote the manager type that is *locally indifferent* between issuing safe debt and issuing only equity, so this type satisfies equation (15). Since the indifference is local (i.e., it is conditional on  $a_i > 0$ ) and does not reflect global optimal choices,  $\lambda \leq 1$  no longer has to hold; Instead, lemma 2 and equation (15) jointly imply that  $\lambda$  is now upper bounded by  $\frac{\gamma}{2\xi}$ , which is greater than one by assumption. As a function of  $\lambda$ , the new cutoff type  $i(\lambda) \in (0, 1)$  that is globally indifferent satisfies

$$V_{i(\lambda)}^d = V^e. \quad (23)$$

Given secondary market loan prices, and hence  $\lambda \in (0, \frac{\gamma}{2\xi}]$ , there will be a unique cutoff type  $i(\lambda) < \lambda$  because  $\zeta_i > 0$  and  $V_i^d$  is monotonic in  $i$ . Moreover, when the entry cost approaches zero, the new cutoff converges to  $\lambda$ : let  $\bar{\zeta} = \max_{i \in \mathcal{I}} \zeta_i$ , it holds that  $\lim_{\bar{\zeta} \rightarrow 0+} i(\lambda) = \lambda$ .

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<sup>40</sup>The monotonicity in  $\eta_i$  can be seen from  $\frac{\partial V_i^d}{\partial \eta_i} = c'^{-1}(y_d) - x_{i,l}(1 - \frac{q_l}{q_h}) > c'^{-1}(y_d) - x_{i,l} > 0$ , where the last inequality follows from assumption 2 because  $y_d > pR + 1 - p$  by lemma 2.

## 5.1 Equilibrium under an Entry Cost

Competitive equilibrium under the policy can be defined similarly as definition 1, except for that asset managers'  $t = 0$  problem takes the entry cost into consideration. If an equilibrium exists, the secondary market clearing condition requires

$$\frac{q_l}{q_h} \int_0^{i(\lambda)} x_{i,l} di = \int_{i(\lambda)}^1 \Delta x_{i,h} di. \quad (24)$$

The limiting property of  $i(\lambda)$  indicates that as  $\bar{\zeta}$  approaches zero, the corresponding aggregate excess demand function  $\chi^{DE}$  converges to  $\chi^{CE}$  of the baseline model.<sup>41</sup> By continuity of the competitive equilibrium in model parameters, an interior equilibrium exists when  $\bar{\zeta}$  is relatively small. Let  $\lambda^{DE}$  and  $i(\lambda^{DE})$  respectively denote the locally indifferent type and cutoff type in the new equilibrium. The following lemma characterizes the relationship among equilibrium cutoff types.

**Lemma 4.** *In equilibrium,  $i(\lambda^{DE}) < \lambda^{CE} < \lambda^{DE}$ .*

*Proof.* See Appendix A □

In addition to distorting intermediary balance sheets, the entry cost policy also affects equilibrium secondary market loan prices. Given the relationship between cutoff type  $\lambda$  and price ratio  $\frac{q_l}{q_h}$  in equation (15), lemma 4 implies that the price ratio increases. Indeed, as fewer managers issue safe debt, there is less portfolio substitution in the negative-news stage and hence less price pressure on risky loans.

So the policy moves equilibrium cutoff and loan prices towards the constrained efficient allocation. Does this imply that the policy corrects the inefficiency of competitive equilibrium? The next proposition provides a negative answer to this question. The result follows immediately from lemma 4 and investment choices as functions of  $\lambda$  in proposition 1.

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<sup>41</sup>The aggregate excess demand functions are defined in the appendix.

**Proposition 3** (Distorted Equilibrium). *The entry cost reduces the fraction of safe debt-financed intermediaries, but nonetheless exacerbates the under-production of safe assets.*

By alleviating asset managers' excessive use of safe debt financing, the entry cost policy increases equilibrium price ratio, which relaxes the remaining safe debt-financed intermediaries' collateral constraints and allows them to issue more safe debt.

Unfortunately, this policy turns out worsening the original problem because it treats only the liability side of a two-sided misallocation. From managers' perspective, a higher price ratio is equivalent to a lower expected return from originating high-quality loans. This reduction in expected return has two effects on investment choices. At the intensive margin, equity-financed intermediaries, who do not internalize the social value of collateral, further under-invest. At the extensive margin, a larger fraction of asset managers give up issuing safe debt and hence choose the worsened investment level. These two effects jointly lead to a reduction in the aggregate 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 9 overlays the competitive allocation (same as panel (b) of Figure 7) and the policy-distorted allocation. While managers  $i \in [0, i(\lambda^{DE})]$  do not change their investment choices, managers now operating equity-financed intermediaries ( $i \in [i(\lambda^{DE}), 1]$ ) all lower their investment levels. This leads to an aggregate reduction in high-quality loans, the quantity of which equals the area of the shaded region. Despite that every safe-debt financed intermediary on average issues more than before ( $\mathbb{E}[a_i^{DE}] > \mathbb{E}[a_i^{CE}]$ ), the market under-produces safe assets to an even greater extent because of a shortage of collateral.

## 5.2 Two-Sided Policy

The previous subsection shows that reducing excessive entry into safe debt issuance worsens the equilibrium by exacerbating the under-investment problem. Similarly frustrating is that a policy forcing equity-financed intermediaries to invest at the socially optimal level also worsens the equilibrium. This is because investing beyond individually optimal level reduces asset managers' payoff, and managers will issue safe debt to escape the scope of this policy.

To correct the two-sided misallocation, it is critical to design a policy that improves both sides of intermediary balance sheets. Specifically, the policymaker should simultaneously reduce entry into safe debt issuance and increase equity-financed intermediaries' investment choices.

If the policymaker's information set includes all model parameters, the implementation of an entry policy is feasible. It can be carried out as, for instance, a lump sum tax on any intermediary that issues safe debt, or a targeted quantity of tradable permits for safe debt issuance. In contrast, subsidizing risky lending could raise concerns over actions not explicitly considered in the model. For instance, a subsidy based on the quantity of origination can have a perverse effect if it incentivizes asset managers to lower screening standard and originate large quantities of low-quality loans.<sup>42</sup>

## 5.3 Credit Risk Retention Regulation

In this subsection, I take the theory's normative implications to shed light on a regulatory debate in the leveraged loan market. The 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

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<sup>42</sup>See the Financial Stability Board report ([FSB, 2019](#)) for potential concerns about the vulnerabilities associated with leveraged loans and CLOs.

requires “sponsors” of securitization transactions to retain at least 5% of un-hedged credit risk of collateral assets for any asset-backed securities. 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.<sup>43</sup> The final rule became effective for residential mortgage-backed securities (RMBS) in December 2015 and for other ABS, including CLOs, in December 2016.

Since the rule’s initial proposal, its inclusion of CLO managers received considerable resistance from practitioners. The major complaint is that CLO managers do not have the capital to buy the securities issued by their CLOs, and the imposed financing cost might drive managers 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 accordingly not subject to the requirements of the Risk Retention Rule. Consequently, CLO managers became exempted from the rule in May 2018.

Although LSTA and asset managers asserted that the regulation has a devastating effect on the CLO business, I first investigate the realized impact.<sup>44</sup> My empirical investigation exploits the fact that virtually the same policy was imposed on the European CLO market before the US market. Figure 10 summarizes the timing of regulatory events and annual average CLO entry rate in the US and European markets between 2000–2019. Before the crisis, an average manager issued more CLOs in the US market, but the time trends were similar. Potentially due to a quick introduction of the risk retention policy in the Europe in the end of 2010, the CLO market there recovered slowly relative to the US market. Since the finalization of the US risk retention policy in late 2014, there has been a salient drop in entry

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<sup>43</sup>See SEC Final Rules 34-73407 for more details.

<sup>44</sup>See Figure A.8 in the Appendix for additional information on practitioner responses to the regulation.



in the US market.<sup>45</sup> This drop in entry rate reversed quickly after the policy gets revoked in early 2018.

This regulation’s impact on CLO entry has important welfare implications. Proposition 3 has shown the equilibrium outcomes under the impact of entry cost imposed by such a regulation. By deterring CLO entry, the policy worsens the under-production of safe assets and therefore exacerbates the inefficiency of the leveraged loan market. Hence, 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.

## 6 Maturity and Commitment

The existing banking literature focuses on a short-maturity mechanism, whereby intermediaries produce riskless debt by allowing creditors to enforce asset liquidation and debt repayment (e.g., [Stein, 2012](#); [Hanson et al., 2015](#)). The model analyzed in previous sections deliberately abstracts from this convention. In this section, I explore two extensions to understand conditions under which long-term contracts with a commitment to maintaining portfolio quality arises as the preferred safe debt contracts.

### 6.1 Safe Debt Maturity

The assumed distributions of risky loan payoffs in the baseline model, as will become clear soon, mechanically discourage asset managers from using short-term safe debt. Moreover, the absence of net cash trades in the secondary market makes early repayment impossible

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<sup>45</sup>Although the policy became effective in 2016, this response is likely due to the fact that CLO equity holders enjoy the option to refinance debt tranches after 2–3 years of non-call period, and the anticipated retention cost added difficulty to equity issuance.

in equilibrium. In this subsection, I relax these assumptions and analyze what drives asset managers' choices of debt maturity. To do so, I extend the model in two aspects. First, I allow risky loans to have general payoff distributions, and second, I introduce outside investors into the secondary market.

Risky loan payoff distributions are generalized as follows. Suppose  $\tilde{R}_j$  is the payoff of loan  $j \in \{h, l\}$ , and the support of its distribution can be any compact subset of  $\mathbb{R}_+$ . A risky loan's fundamental values conditional on news at  $t = 1$  are denoted by  $R_j := \mathbb{E}[\tilde{R}_j | \text{positive news}]$  and  $F_j := \mathbb{E}[\tilde{R}_j | \text{negative news}]$ . In addition, let  $r_j$  and  $f_j$  be the lower bounds of the supports of the corresponding conditional distributions. For simplicity, I assume  $r_j > F_j$  for  $j \in \{h, l\}$ . I also normalize  $f_h > f_l = 0$ , so low-quality loans are indeed less valuable in securing safe debt.<sup>46</sup>

There is a costly technology that allows households to store their endowed consumption goods from date  $t = 0$  to date  $t = 1$ . I interpret this storage technology as the formation of specialized capital for buying liquidated assets during market downturns, such as distressed debt strategy funds. Storing each unit of goods incurs a constant cost  $\kappa > 0$ . This linear participation cost structure implies that outside investors' demand for loan  $j$  in the secondary market is

$$z(q_j) = \begin{cases} +\infty, & (1-p)\left(\frac{F_j}{q_j} - 1\right) > \kappa \\ \forall z \in \mathbb{R}_+, & (1-p)\left(\frac{F_j}{q_j} - 1\right) = \kappa \\ 0, & (1-p)\left(\frac{F_j}{q_j} - 1\right) < \kappa \end{cases} \quad (25)$$

The market clearing condition thus becomes

$$\int_{i \in \mathcal{I}} \Delta x_{i,j} \, di + \frac{z(q_j)}{q_j} = 0 \quad (26)$$

for  $j \in \{h, l\}$ . Since this capital is the only source of liquidity outside of the intermediary sector, it pins down the levels of secondary market loan prices in equilibrium.

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<sup>46</sup>Accordingly, assumption 2 is generalized to  $c'(\bar{x}_l) < pR_h + (1-p)F_h$ .

Under these assumptions, an asset manager can flexibly choose between short-term and long-term debt contracts as long as the debt is safe. The manager's  $t = 0$  initial collateral constraint becomes

$$x_{i,h}q_h + x_{i,l}q_l \geq \min \left\{ a_i \frac{q_h}{f_h}, a_i \right\}. \quad (\text{ICC}')$$

This constraint requires the intermediary's portfolio value to be enough to ensure debt safety at the negative-news stage, either through portfolio substitution or early repayment. Clearly, which type of balance sheet adjustment allows for a larger safe debt capacity depends on the level of price  $q_h$  relative to the loan's worst possible payoff  $f_h$ . When  $q_h \leq f_h$ , long-term contract maximizes safe debt capacity, and short-term contract maximizes debt capacity when  $q_h > f_h$ . After an intermediary issues short-term safe debt, the debt can be rolled over at  $t = 1$  if the manager is both able and willing to hold enough collateral; otherwise, she repays the debt. The rollover case can be interpreted as equivalent to long-term safe debt.

I first analyze the manager's secondary market problem, taking choices at  $t = 0$  and loan prices as given. In the positive-news stage, debt rolls over, and no trade occurs. When negative news arrives at  $t = 1$ , the manager solves

$$v(x_{i,h}, x_{i,l}, a_i) = \max_{\Delta x_{i,h}, \Delta x_{i,l}, \Delta a_i} \sum_j (x_{i,j} + \Delta x_{i,j}) F_j - (a_i + \Delta a_i), \quad (27)$$

where  $\Delta a_i$  is the net change in debt outstanding (i.e.,  $\Delta a_i < 0$  is a repayment). She faces budget constraint

$$\sum_j x_{i,j} q_j + \Delta a_i \geq \sum_j (x_{i,j} + \Delta x_{i,j}) q_j, \quad (\text{BC}')$$

maintenance collateral constraint

$$(x_{i,h} + \Delta x_{i,h}) f_h \geq a_i + \Delta a_i, \quad (\text{MCC}')$$

and short-sale constraints  $\Delta x_{i,h} \geq -x_{i,h}, \Delta x_{i,l} \geq -x_{i,l}, -a_i \leq \Delta a_i \leq 0$ . Similar to the

baseline model, this problem can be simplified to

$$\max_{\Delta x_{i,l}, \Delta a_i} \Delta x_{i,l} \left( F_l - F_h \frac{q_l}{q_h} \right) + \left( \frac{F_h}{q_h} - 1 \right) \Delta a_i, \quad (\text{P1}')$$

subject to constraints

$$\Delta x_{i,l} f_h \frac{q_l}{q_h} + \Delta a_i \left( 1 - \frac{f_h}{q_h} \right) \leq x_{i,h} f_h - a_i, \quad (28)$$

and  $\Delta x_{i,l} \geq -x_{i,l}$ ,  $-a_i \leq \Delta a_i \leq 0$ .

The manager's optimal choices that solve problem (P1') depend on both balance sheet at  $t = 0$  and loan prices at  $t = 1$ , which jointly determine what choices are ex-post desirable and feasible. In the Appendix, I show that early repayment ( $\Delta a_i = -a_i$ ) is ex-post desirable if and only if  $q_h > f_h^+ := f_h + \frac{q_l}{F_l}(F_h - f_h)$ . That is, the manager wants to repay debt early if and only if  $q_h$  is sufficiently higher than  $q_l$ . In this case, after the repayment, the manager can hold only low-quality loans and expect a high equity return. When  $q_h \leq f_h^+$ , delaying repayment by holding enough collateral is desirable. Moreover, the feasibility of these actions is pre-determined by inequality (ICC'). If a desirable action is ex-post infeasible, the manager has to choose an undesirable action to satisfy the collateral constraint.<sup>47</sup>

Intuitively, the manager's safe debt maturity choice at  $t = 0$  is based on a tradeoff between ex-ante safe debt capacity and ex-post liquidation costs, both of which depend on secondary market loan prices. Since outside investors can potentially absorb liquidated loans, loan prices are eventually related to their funding cost. The following proposition summarizes the set of competitive equilibria that can arise in this generalized economy.

**Proposition 4** (Equilibrium with Safe Debt Maturity Choice). *Depending on parameter values, there are four types of competitive equilibrium:*

(i) *Long-term safe debt and equity financing coexist. There exists a unique  $\lambda^t \in (0, 1)$*

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<sup>47</sup>For instance, when short-term contract allows for more safe debt capacity and a manager chooses to do so (i.e.,  $a_i \leq x_{i,h} q_h + x_{i,l} q_l < a_i \frac{q_h}{f_h}$ ), the manager has to repay debt in the negative-news stage even if her desired action is to rollover debt.

such that managers  $[0, \lambda^{lt}]$  issue long-term safe debt, and the rest issue only equity. Secondary market loan prices satisfy  $q_h \leq f_h + \frac{1}{\gamma}(1-p)(F_h - f_h)$ ,  $q_l \geq \frac{(1-p)F_l}{1-p+\kappa}$ ,  $\frac{q_l}{q_h} < \frac{F_l}{F_h}$ , and no risky loan is sold to outside investors.

(ii) Short-term and long-term safe debt, and equity financing coexist. There exist a unique pair of  $\lambda^{st}, \lambda^{lt}$ , where  $0 < \lambda^{st} < \lambda^{lt} < 1$ , such that managers  $[0, \lambda^{st}]$  issue short-term safe debt,  $(\lambda^{st}, \lambda^{lt}]$  issue long-term safe debt, and the rest issue only equity. Secondary market loan prices satisfy  $q_h = f_h + \frac{1}{\gamma - \xi_{\lambda^{st}}}(1-p)(F_h - f_h)$ ,  $q_l = \frac{(1-p)F_l}{1-p+\kappa}$ , and  $\frac{q_l}{q_h} < \frac{F_l}{F_h}$ . A subset of low-quality loans is sold to outside investors.

(iii) Short-term and long-term safe debt financing coexist. There exists a unique  $\lambda^{st} \in (0, 1)$  such that managers  $[0, \lambda^{st}]$  issue short-term safe debt, and the rest issue long-term safe debt. Secondary market loan prices satisfy  $q_h = f_h + \frac{1}{\gamma - \xi_{\lambda^{st}}}(1-p)(F_h - f_h)$ ,  $q_l = \frac{(1-p)F_l}{1-p+\kappa}$ , and  $\frac{q_l}{q_h} \in \left( \frac{(1-p)F_l}{(1-p)F_h + (\gamma - 2\xi)f_h}, \frac{F_l}{F_h} \right)$ . All low-quality loans are sold to outside investors.

(iv) Universal short-term safe debt financing. All managers issue short-term safe debt. Secondary market loan prices are  $q_j = \frac{(1-p)F_j}{1-p+\kappa}$ ,  $j \in \{h, l\}$ , and all risky loans are sold to outside investors.

*Proof.* See Appendix A. □

Type-i equilibrium arises when outsiders' funding cost is large with respect to the safety premium. In this equilibrium, the high-quality loan's price is low, hence the short-term contract either fails to maximize safe debt capacity, or the benefit of its capacity advantage is smaller than the cost of early liquidation. As a result, all safe debt-financed intermediaries use long-term contracts and substitute collateral in the secondary market. A subset of intermediaries issue only equity and profit from secondary market trades. The baseline model is a special case that satisfies the low-price condition, so it is without loss of generality to

restrict attention to long-term safe debt contract.<sup>48</sup>

Type-ii and type-iii equilibria feature a “pecking order” in safe debt maturity choices. While short-term contract maximizes safe debt capacity, it is more costly to liquidate loans than to substitute collateral ex post. A greater safe debt capacity is more valuable for managers with better securitization expertise. In equilibrium, only managers with sufficiently low issuance costs use short-term contract to maximize capacity, and other intermediaries issue long-term safe debt or only equity. In the negative-news stage, the first group of intermediaries liquidate all risky loans, whereas the second and third (if any) groups substitute collateral. Outside investors absorb only low-quality loans, which provide a higher return. High-quality loans change hands among intermediaries.

Type-iv equilibrium arises when outsiders’ funding cost is small with respect to the safety premium. In this equilibrium, risky loans do not experience a severe secondary market price discount, so the cost of early liquidation is smaller than the benefit of maximizing safe debt capacity. Hence, all intermediaries optimally issue short-term safe debt to enjoy cheap financing and liquidate their entire holdings of risky loans when negative news arrives. For the secondary market to clear, risky loans must offer the same expected return:  $\frac{q_l}{q_h} = \frac{F_l}{F_h}$ . Unlike equilibrium types i–iii, no intermediary’s debt safety relies on collateral originated by others, and the constrained inefficiency associated with portfolio substitution does not arise in this equilibrium.

## 6.2 Information Frictions and Limited Commitment

So far, it has been assumed that asset managers can credibly commit to future actions contingent on news at  $t = 1$ . This assumption simplifies the analysis, but it is admittedly

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<sup>48</sup>The payoff distribution in Section 3.1 dictates that  $F_h = f_h = 1$ , so mechanically,  $q_h \leq f_h$ . This implies that short-term contract not only fails to maximize safe debt capacity, but also leads to lower ex-post payoff to a manager given the quantity of safe debt issued.

unrealistic for two reasons. First, asset managers have access to non-public information and thus can better assess loan quality than investors do. Second, managers still cannot perfectly observe the quality of a risky loan. Although there exist publicly verifiable proxies associated with a loan's quality (e.g., credit ratings), contracting based on these proxies as if they accurately measure loan quality is unlikely to force managers to ensure debt safety. In this subsection, I briefly discuss whether and how the debt contract can be modified to accommodate such contractual frictions.

I introduce the following generalization that allows loan types to be imperfectly contractible: A debt contract that requires a quantity  $m_i \in \mathbb{R}_+$  of high-quality loans can only enforce

$$\hat{x}_{i,h} + \Delta x_{i,h} + \rho(x_{i,l} + \Delta x_{i,l}) \geq m_i. \quad (29)$$

The left hand side of (29) can be interpreted as the quantity of pre-trade qualified risky loans that will continue to satisfy the contract's requirement after secondary market trades. From the manager's perspective, every unit of high-quality loans will continue to be qualified with certainty, whereas each unit of low-quality loans that is pre-trade qualified has only a  $\rho \in (0, 1)$  chance of being qualified post trade. Parameter  $\rho$  thus captures the manager's limited commitment due to noises in loan quality proxies. The larger  $\rho$  is, the more low-quality loans the manager can mix into the required quantity  $m_i$  of qualified holdings. As  $\rho$  approaches zero (one), managers approach full (zero) commitment. Moreover, managers' information is imperfect. In particular, a manager's perceived quantity of high-quality loans,  $\hat{x}_{i,h}$ , includes an unobservable low-quality component:  $\hat{x}_{i,h} = x_{i,h} + \hat{\epsilon}_i$ , where  $\hat{\epsilon}_i$  is independent and identically distributed over  $(0, \bar{\epsilon}] \subset \mathbb{R}_+$  and  $\bar{\epsilon} < c'^{-1}(pR + 1 - p) - \bar{x}_l$ .

When negative news arrives, asset managers privately prefer low-quality loans to high-quality loans. This risk-shifting incentive and imperfect information imply that the contract in Section 3 inevitably fails to ensure debt safety. Specifically, if the contract specifies  $m_i = a_i$ , the manager would "reach for yield" by choosing a post-trade portfolio with

$x_{i,h} + \Delta x_{i,h} < \hat{x}_{i,h} + \Delta x_{i,h} \leq a_i$  because low-quality loans have a higher expected return ( $q_l/q_h < \pi$ ). This contractual failure implies that the portfolio's payoff in state  $s = d$  is insufficient to pay back debt, and the debt defaults with a positive probability.<sup>49</sup>

The debt contract can still rely on verifiable loan quality proxies to address the informational and agency frictions. An arrangement that potentially restores debt safety is over-collateralization. This provision requires the quantity of qualified risky loans to be no less than safe debt face value plus an additional quantity  $a_i^{oc} > 0$ :

$$\hat{x}_{i,h} + \Delta x_{i,h} + \rho(x_{i,l} + \Delta x_{i,l}) \geq m_i = a_i + a_i^{oc}. \quad (\text{OC})$$

The manager's secondary market budget constraint suggests that she can mix one unit of low-quality loans into qualified holdings at the cost of  $\frac{q_l}{q_h}$  units of actual high-quality loans. Meanwhile, this unit of low-quality loans only fulfills  $\rho$  units towards the requirement. When  $\rho$  is relatively small, mixing in low-quality loans reduces the quantity of qualified holdings in the portfolio. In this case, the manager's risk shifting upon the arrival of negative news is constrained by the quantity of low-quality loans that she can possibly hold without violating the over-collateralization requirement. Hence, by setting a sufficiently large  $a_i^{oc}$ , the contract forces the manager to include enough high-quality loans in the adjusted portfolio. In contrast, when  $\rho$  is large, the left hand side of (OC) would be increasing in  $\Delta x_{i,l}$ , relaxing this inequality constraint as the manager increases portfolio risk. Based on this intuition, the following proposition characterizes the conditions for debt safety to be achievable.

**Proposition 5** (Over-Collateralization). *The contract implements debt safety if and only if the over-collateralization requirement  $a_i^{oc}$  satisfies*

$$\rho \left( (x_{i,h} - a_i) \frac{q_h}{q_l} + x_{i,l} \right) + \bar{\epsilon} \leq a_i^{oc} \leq \left( (x_{i,h} - a_i) \frac{q_h}{q_l} + x_{i,l} \right) \frac{q_l}{q_h}. \quad (30)$$

*Proof.* See Appendix A. □

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<sup>49</sup>Note that paying the manager an incentive fee conditional on that debt does not default cannot prevent the risk shifting behavior as long as the bonus comes as part of portfolio payoff.



This result indicates that perfect contractibility is not a necessary condition for secondary market trading to increase safe debt capacity. As long as the proxies for loan quality allow the contract to sufficiently constrain the manager’s portfolio choices, promised trades can be implemented with over-collateralization.<sup>50</sup> The secondary market price ratio  $\frac{q_l}{q_h}$  plays an important role in this contract: First, a deeply depressed price ratio compromises the constraint on the manager’s risk shifting, and second, the ratio also has to be sufficiently greater than  $\rho$  for condition (30) to be feasibly satisfied.

## 7 Concluding Remarks

The rise of shadow banking, particularly securitization, is largely attributable to the demand for safe assets. Nonbank financial intermediaries attempted to produce safe assets in the form of collateralized long-term debt securities, but many of such assets failed miserably during the financial crisis. They failed because the quality of their static collateral portfolios deteriorated after adverse systemic shocks. This paper analyzes the idea of using dynamic collateral portfolios to address this challenge. The mechanism is best exemplified by CLOs, an increasingly large group of intermediaries that have been producing safe assets for decades and have not ever failed.

At the core of this mechanism is a commitment to dynamically maintaining collateral quality thorough secondary market trades. By making this commitment, a CLO manager increases its ex-ante safe debt capacity but bears the ex-post cost of reverse risk shifting trades in bad times. This paper develops an equilibrium model of safe asset production, in which CLOs and other intermediaries endogenously coexist and trade as counterparties in bad times. The empirical findings and analytical insights in this paper provide an equilibrium view of the leveraged loan market and useful policy implications.

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<sup>50</sup>If  $x_{i,l}$  is unobservable, the lower bound of  $a_i^{ec}$  can be implemented with  $\rho(x_i - a_i)\frac{q_h}{q_l} + \bar{\epsilon}$  instead.

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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 their choices of investment vehicles.**

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.





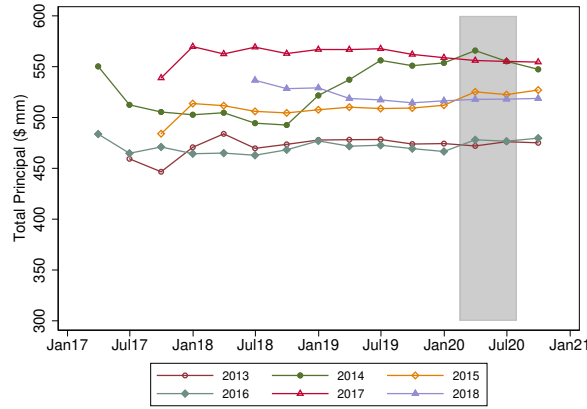
(a) CLOs in Reinvestment Period



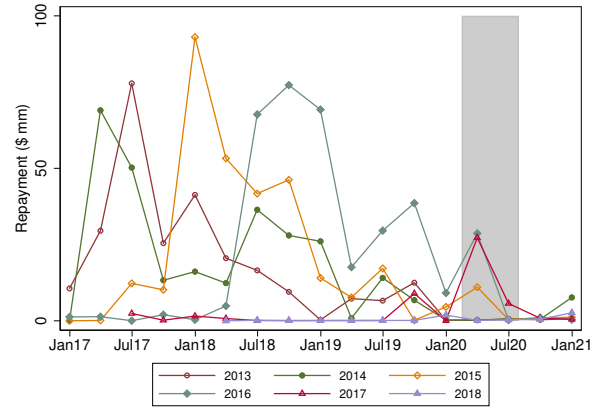
(b) CLOs in Amortization Period

Figure 3: **Slackness of senior tranche over-collateralization constraint.**

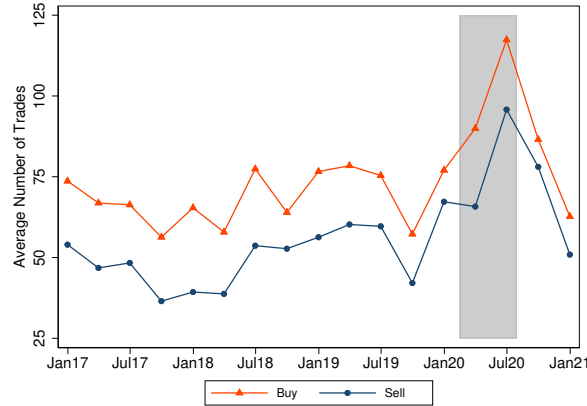
This figure presents quarterly time series of cross-sectional dispersion in the slackness of CLO senior tranche over-collateralization (OC) constraints between 2010–2019. The slackness is defined as extra OC score scaled by the OC test’s predetermined threshold level. Dashed lines indicate 5th and 95th percentiles in each cross section. Panel (a) reports CLOs in reinvestment period, and panel (b) reports CLOs in amortization period.



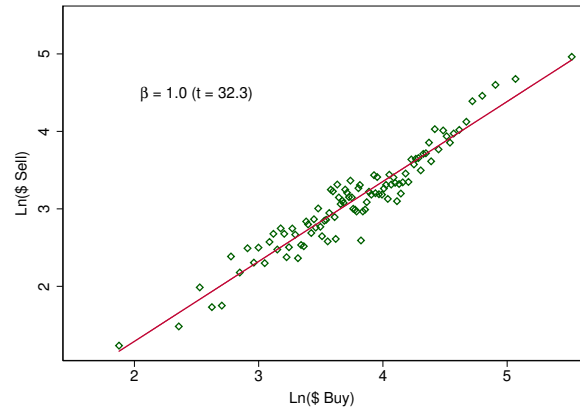
(a) Portfolio Total Loan Holdings



(b) Accelerated Debt Repayment



(c) Quarterly Loan Trades



(d) Individual CLOs' Purchases and Sales

Figure 4: **Balance sheet dynamics around the onset of COVID-19 pandemic.**

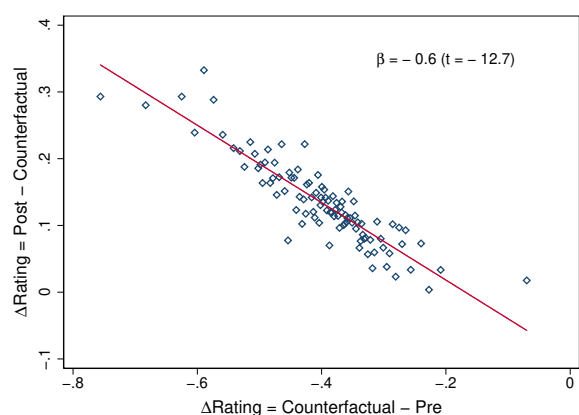
This figure shows quarterly changes in CLOs' assets and liabilities before and during the COVID-19 shock in 2020. Panel (a) plots average CLO total loan holdings by issuance year cohort. Panel (b) plots average CLO accelerated principal repayment of AAA tranches by issuance year cohort. Panel (c) plots average numbers of loan purchases and sales during a quarter. Panel (d) is a scatter plot that groups CLOs into 100 bins based on natural logarithms of individual CLOs' loan buy and sell dollar volumes during the first two quarters of 2020. Only CLOs in reinvestment period are included.



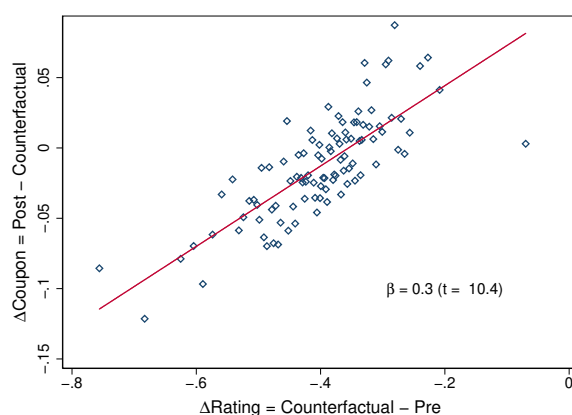
(a) Slackness of OC Constraint (%)



(b) Portfolio Value-Weighted Average Rating



(c) Quality Improvement: Rating



(d) Quality Improvement: Coupon



(e) Trading Direction: Rating



(f) Trading Direction: Coupon

Figure 5: **Portfolio substitution improves collateral quality.**

This figure shows the effect of portfolio substitution on CLOs' collateral quality between February 15 and June 30 of 2020. Panel (a) plots kernel density estimates for the distribution of senior OC constraint slackness before and after the onset of COVID-19 pandemic. Panel (b) plots kernel density estimates for the distribution of value-weighted average credit rating for portfolios before and after the shock as well as counterfactual static portfolios. Panels (c)-(f) are scatter plots that group CLOs into 100 bins by counterfactual collateral deterioration and depict the average effect of loan trading within each bin. The fitted lines represent OLS estimates, and t-statistics are based on heteroskedasticity-robust standard errors. Only CLOs in reinvestment period (87%) are included.

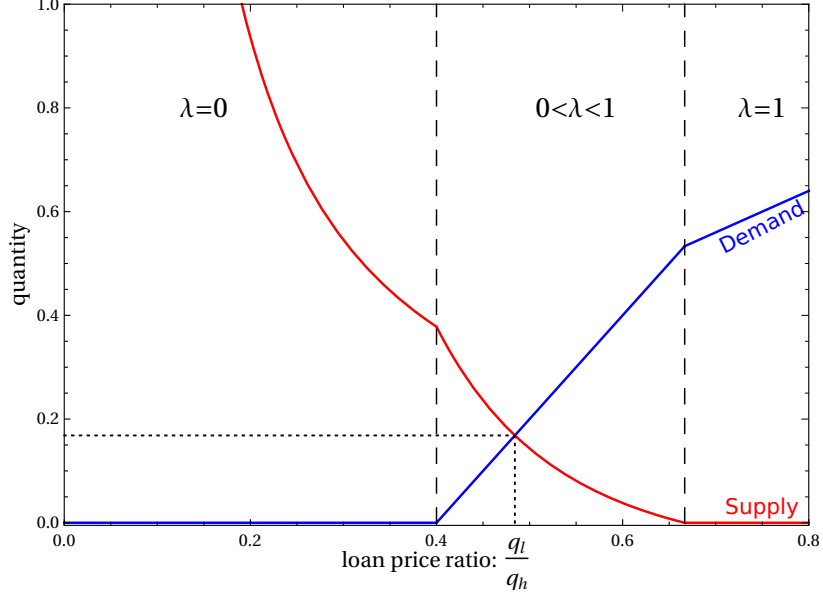


(a) Leveraged Loans

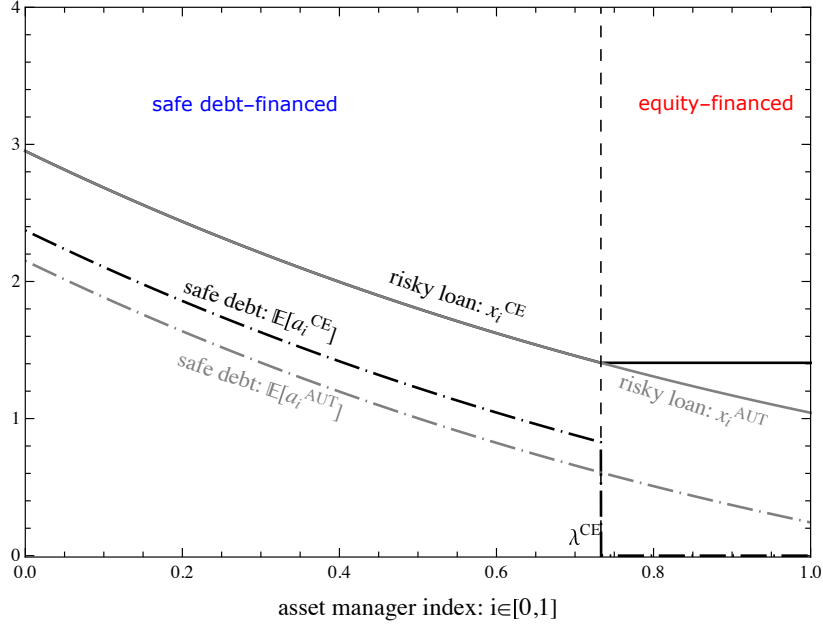


(b) High-Yield Bonds

**Figure 6: Secondary market price drops during COVID-19 crisis.** This figure plots average transitory secondary market price drop in March 2020 for corporate debts within each credit rating group. In Panel (a), leveraged loans prices are based on reported market values in CLO portfolio holdings. In Panel (b), high yield corporate bond prices are based on reported market values in corporate bond mutual fund portfolio holdings. Price drop is measured as the decrease in secondary market price in March 2020 relative to the average price before and after the COVID-19 shock. The vertical lines indicate 95% confidence intervals for group means.



(a) Secondary market demand and supply



(b) The cross section of balance sheet choices

**Figure 7: Competitive equilibrium.**

This figure numerically illustrates the competitive equilibrium. Panel (7a) plots aggregate secondary market demand and supply for high-quality loans as functions of the loan price ratio. Panel (7b) plots the cross section of investment and financing choices in competitive equilibrium, where  $x_i^{CE}$  and  $\mathbb{E}[a_i^{CE}]$  denote equilibrium quantities of risky loan origination and expected safe debt issuance by manager  $i$ , respectively. Functional form and parameter values:  $c(x) = x^{1.2}$ ,  $p = 0.95$ ,  $R = 1.2$ ,  $\pi = 0.8$ ,  $\gamma = 0.3$ ,  $\xi = 0.14$ ,  $x_L = 0.8$ .

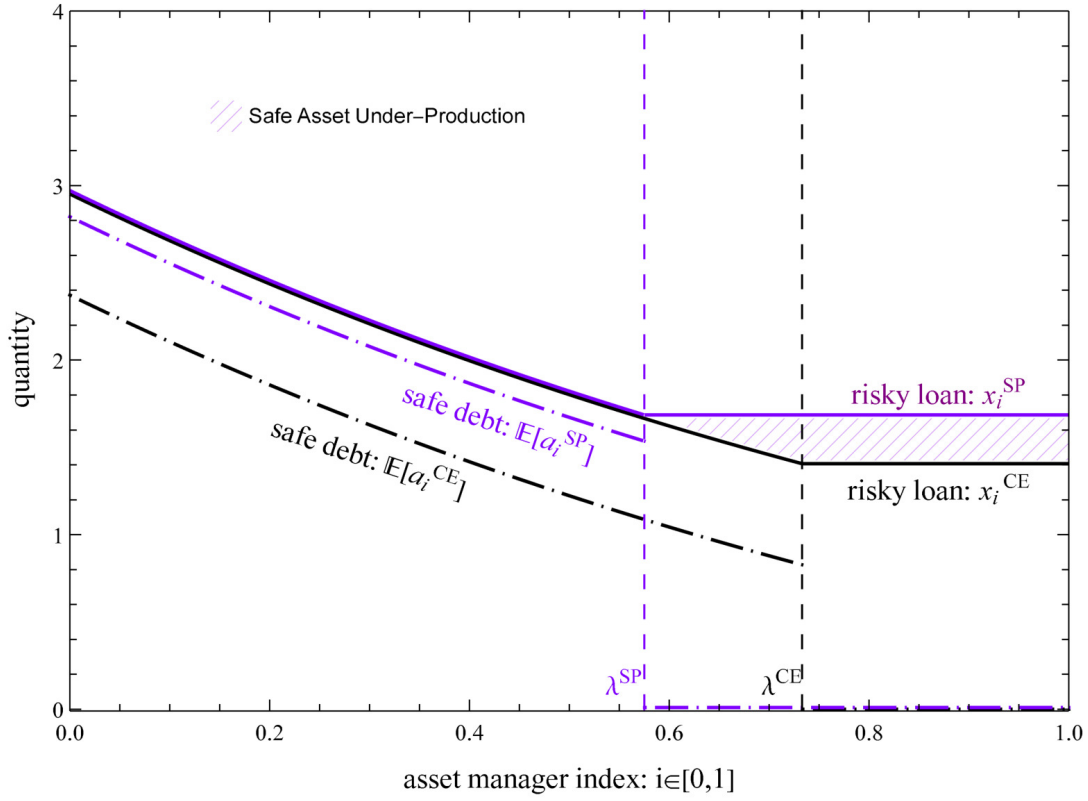


Figure 8: **Constrained inefficiency of the equilibrium.**

This figure numerically illustrates the differences between competitive allocation and social planner's allocation. Superscripts CE and SP indicate the competitive and planned allocations, and  $x_i$  and  $\mathbb{E}[a_i]$  denote the quantities of risky loan origination and expected safe debt issuance by manager  $i$ , respectively. The area of the shaded region represents the quantity of under-production of safe assets in competitive equilibrium. Functional form and parameter values are the same as in Figure 7.

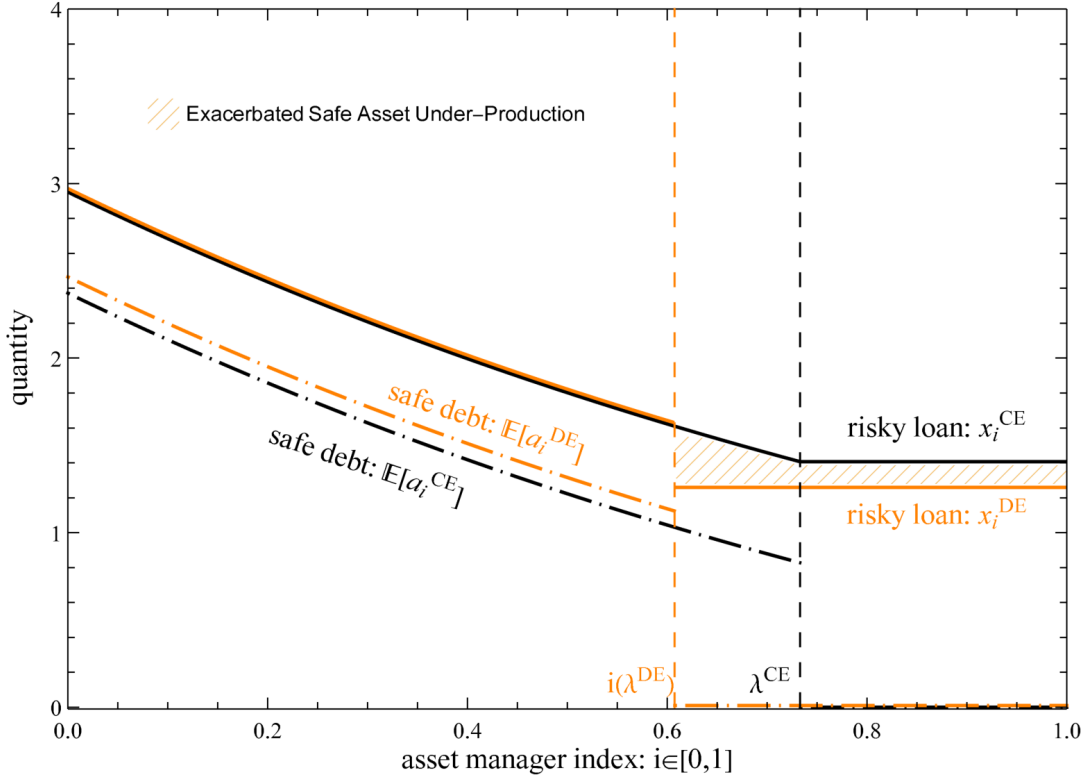


Figure 9: **Equilibrium distorted by the entry cost policy.**

This figure numerically illustrates competitive allocation when an entry cost is imposed on safe debt-financed intermediaries. Superscripts CE and DE indicate the original and distorted competitive allocations, and  $x_i$  and  $\mathbb{E}[a_i]$  denote the quantities of risky loan origination and expected safe debt issuance by manager  $i$ , respectively. The area of the shaded region represents the quantity of incremental under-production 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 7.

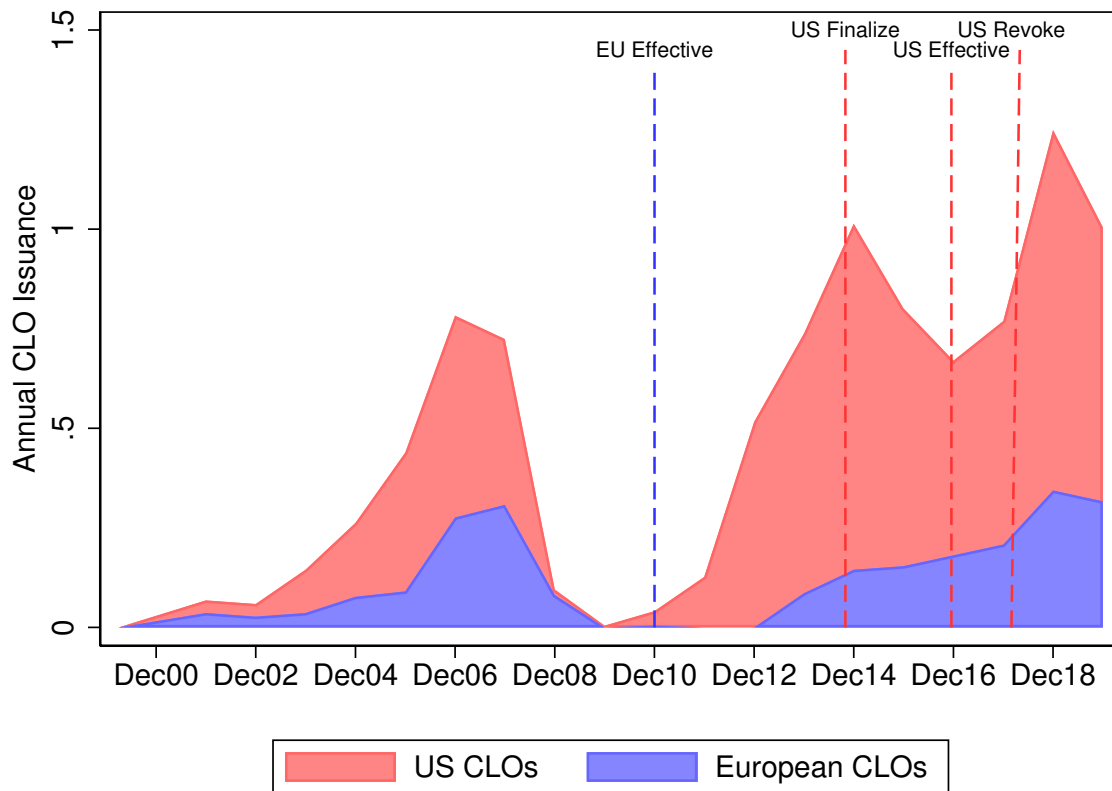


Figure 10: **Risk retention and CLO entry in the US and European markets.**

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

## A Proofs

**Proof of Lemma 1.** In autarky,  $\Delta x_{i,h} = \Delta x_{i,l} = 0$ , and the initial collateral constraint (ICC) becomes  $a_i \leq x_{i,h}$ . The objective in (P0) is strictly increasing in  $a_i$  by Assumption 1, so  $a_i^{AUT} = x_{i,h}$ . 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  $x_i^{AUT}$ .

**Proof of Lemma 2.** Suppose otherwise (i.e.,  $\frac{q_l}{q_h} > \pi$ ), 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.

**Proof of Lemma 3.** The complementary slackness condition (8) 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 (7) 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 (14) is 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  $\{a_i : a_i \leq x_{i,h} + x_{i,l} \frac{q_l}{q_h}\}_{i \in \mathcal{I}}$  that satisfies equation (14) is an equilibrium. Apply similar arguments to the planner's Kuhn-Tucker conditions (11)-(13), 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  $\{a_i : a_i \leq x_{i,h} + x_{i,l} \pi\}_{i \in \mathcal{I}}$  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 1.** If a competitive equilibrium exists, the cutoff type's indifference

condition (15) implies that

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

which is well-defined and strictly positive by assumption 1. The two groups of intermediaries' primary market investment choices follow from substituting  $\eta_i$  and (1) into (6). Given the two groups' optimal safe debt choices and secondary market trades in (4), the market clearing condition can be rewritten as

$$\frac{q_l}{q_h} \int_0^\lambda x_{i,l} di = \int_\lambda^1 x_{i,h} di. \quad (2)$$

By law of large numbers,  $\int_0^\lambda x_{i,l} di = \lambda x_L$ , and  $\int_\lambda^1 x_{i,h} di = (1-\lambda)(x_i - x_L)$ . Both  $\frac{q_l}{q_h}$  and  $x_i$  can be expressed as functions of  $\lambda$ , so the two equations (1) and (2) are equivalent to a single condition  $\chi^{CE}(\lambda) = 0$ , where the aggregate excess demand  $\chi^{CE} : [0, 1] \mapsto \mathbb{R}$  is defined as:

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

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  $c$ ,  $\chi^{CE}$  is continuous and strictly increasing on  $[0, 1]$ , so the root is unique.

Similarly, 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  $\xi_i$  in  $i$ , equation (12) 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 with debt issuance for the cutoff type  $i = \lambda$ , which satisfies  $\psi^{SP} = \gamma - \xi_\lambda$ .

The planner's investment choices follow from substituting  $\eta_i^{SP} = \max\{\xi_\lambda - \xi_i, 0\}$  and  $\psi^{SP} = \gamma - \xi_\lambda$  into (11). Given the cutoff property, the binding constraint (ACC) is equivalent

to

$$\pi \int_0^\lambda x_{i,l} di = \int_\lambda^1 (x_i - x_{i,l}) di, \quad (4)$$

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

$$\chi^{SP}(\lambda) = \pi \lambda x_L - (1 - \lambda) \left( c'^{-1}(pR + 1 - p + \gamma - 2\xi\lambda) - x_L \right). \quad (5)$$

Similar to  $\chi^{CE}$  defined in (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.

**Proof of Proposition 2.** 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  $\chi^{SP}$ . Using aggregate relationship  $A = X - x_L$ , it follows that

$$A^{SP} - A^{CE} = X^{SP} - X^{CE} = \int_{\lambda^{SP}}^1 (x_i^{SP} - x_i^{CE}) di > 0 \quad (6)$$

because  $x_i^{SP} > x_i^{CE}$  for any  $i \in (\lambda^{SP}, 1]$  by equations (16) and (19).

**Proof of Lemma 4.** The proof is by contradiction and consists of two steps. Both steps are constructed using the cutoff type condition (15), the market clearing condition (2), and individually optimal investment choices (16) in proposition 1. The aggregate excess demand equation in policy-distorted market is

$$\chi^{DE}(\lambda) = \frac{q_l}{q_h} \int_0^{i(\lambda)} x_{i,l} di - \int_{i(\lambda)}^1 (x_i - x_{i,l}) di. \quad (7)$$

For expositional convenience, I use superscript  $CE$  to label variables in competitive equilibrium, and I use  $DE$  to label variables in the distorted equilibrium under consideration.

**Step 1:** Suppose  $\lambda^{DE} < \lambda^{CE}$ , and hence  $i(\lambda^{DE}) < \lambda^{DE} < \lambda^{CE}$ . By equation (15), this

implies  $(\frac{q_l}{q_h})^{DE} < (\frac{q_l}{q_h})^{CE}$ , and hence

$$\left(\frac{q_l}{q_h}\right)^{DE} \int_0^{i(\lambda^{DE})} x_{i,l} di < \left(\frac{q_l}{q_h}\right)^{DE} \int_0^{\lambda^{CE}} x_{i,l} di < \left(\frac{q_l}{q_h}\right)^{CE} \int_0^{\lambda^{CE}} x_{i,l} di. \quad (8)$$

For equity-financed intermediaries, by equation (16), the hypothesized inequality also implies  $x_i^{DE} > x_i^{CE}$ , which further implies

$$\int_{i(\lambda^{CE})}^1 x_i^{DE} di > \int_{\lambda^{CE}}^1 x_i^{DE} di > \int_{\lambda^{CE}}^1 x_i^{CE} di. \quad (9)$$

Given equation (2),

$$\left(\frac{q_l}{q_h}\right)^{CE} \int_0^{\lambda^{CE}} x_{i,l} di = \int_{\lambda^{CE}}^1 (x_i^{CE} - x_{i,l}) di, \quad (10)$$

so inequalities (8) and (9) jointly imply

$$\left(\frac{q_l}{q_h}\right)^{DE} \int_0^{i(\lambda^{DE})} x_{i,l} di < \int_{i(\lambda^{CE})}^1 (x_i^{DE} - x_{i,l}) di. \quad (11)$$

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

**Step 2:** Suppose  $\lambda^{CE} < i(\lambda^{DE}) < \lambda^{DE}$ . Using similar arguments as in Step 1, this inequality implies

$$\left(\frac{q_l}{q_h}\right)^{DE} \int_0^{i(\lambda^{DE})} x_{i,l} di > \int_{i(\lambda^{CE})}^1 (x_i^{DE} - x_{i,l}) di, \quad (12)$$

which is a contradiction too. Hence, the regulation-distorted competitive equilibrium satisfies  $i(\lambda^{DE}) < \lambda^{CE} < \lambda^{DE}$ .

**Proof of Proposition 4.** The proof builds on the observation that  $\Delta a_i = -a_i$  is ex-post desirable if and only if  $q_h > f_h^+ := f_h + \frac{q_l}{F_l}(F_h - f_h)$ . To see that  $q_h > f_h^+$  is sufficient, note that it implies  $\frac{q_h}{F_h} > \frac{q_l}{F_l} + \frac{f_h}{F_h} \left(1 - \frac{q_l}{F_l}\right) \geq \frac{q_l}{F_l}$ , so constraint (28) binds: the objective in problem (P1') then reduces to  $\Delta a_i \frac{F_l(f_h^+ - q_h)}{f_h q_l}$ , which strictly decreases in  $\Delta a_i$ . It can be easily seen from above that  $q_h > f_h^+$  is necessary when  $\frac{q_l}{F_l} < \frac{q_h}{F_h}$ ; When  $\frac{q_l}{F_l} \geq \frac{q_h}{F_h}$ ,  $\Delta a_i = -a_i$  is not desirable

because optimal  $\Delta x_{i,l} = -x_{i,l}$ , and the objective reduces to  $\Delta a_i \left( \frac{F_h}{q_h} - 1 \right)$ , which strictly increases in  $\Delta a_i$ .

Competitive equilibria with safe debt maturity choices can be found by searching over three mutually exclusive cases.

**Case 1:**  $q_h \in (0, f_h]$ . In this case, short-term contract is strictly dominated because long-term contract maximizes ex-ante safe debt capacity ( $a_i \frac{q_h}{q_l} \leq a_i$ ), and  $\Delta a_i = 0$  is ex-post desirable. All safe-debt financed intermediaries will use long-term contract. Similar to the baseline model, the competitive equilibrium has an interior cutoff and is unique with respect to price ratio  $\frac{q_l}{q_h} < \frac{F_l}{F_h}$ . Secondary market clearing conditions imply that no risky loan is sold to outsider investors. So in this equilibrium,  $q_l \geq \frac{(1-p)F_l}{1-p+\kappa}$ . The equilibrium exists when  $\kappa$  is relatively large with respect to  $\gamma$ .

**Case 2:**  $q_h \in (f_h, f_h^+]$ . In this case, short-term contract maximizes ex-ante safe debt capacity ( $a_i \frac{q_h}{q_l} > a_i$ ), but  $\Delta a_i = 0$  is ex-post desirable. An analog of lemma 2 holds:  $\frac{q_l}{q_h} \leq \frac{F_l}{F_h}$ , otherwise there is either zero demand for low-quality loans or infinite demand for high-quality loans.<sup>51</sup> Hence, constraint (28) binds, and optimal secondary market trades can be derived accordingly. There are generally three liability types for asset managers to choose from:

- (i) If an intermediary issues only equity, optimal secondary market trades are  $\Delta x_{i,h} = -x_{i,h}$ ,  $\Delta x_{i,l} = x_{i,h} \frac{q_h}{q_l}$ , and continuation value  $v^e = (x_{i,h} \frac{q_h}{q_l} + x_{i,l})F_l$ . The manager's marginal payoff from originating risky loans is  $y_i^e := pR_h + (1-p)F_l \frac{q_h}{q_l}$ , and her payoff is

$$V_i^e = y_i^e c'^{-1}(y_i^e) - c(c'^{-1}(y_i^e)) - x_{i,l} \left( p(R_h - R_l) + (y_i^e - pR_h) \left( 1 - \frac{q_l}{q_h} \right) \right). \quad (13)$$

- (ii) If an intermediary issues long-term safe debt, optimal secondary market trades are

$$\Delta x_{i,h} = \frac{a_i}{f_h} - x_{i,h}, \Delta x_{i,l} = (x_{i,h} - \frac{a_i}{f_h}) \frac{q_h}{q_l}, \text{ and continuation value } v^{lt} = (x_{i,h} \frac{q_h}{q_l} + x_{i,l})F_l - a_i \left( 1 + \frac{q_h F_l}{q_l f_h} - \frac{F_h}{f_h} \right). \text{ At } t = 0, \text{ the manager faces constraint } a_i \leq (x_{i,h} + x_{i,l} \frac{q_l}{q_h})f_h, \text{ with}$$

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<sup>51</sup>For different intermediary liability types, see below for the corresponding optimal secondary market trades, which are derived from problem (P1').

shadow price  $\eta_i^{lt} = \max\{\gamma - \xi_i - (1-p)(\frac{q_h F_l}{q_l f_h} - \frac{F_h}{f_h}), 0\}$ . When  $\eta_i^{lt} > 0$ , her marginal payoff from originating risky loans is  $y_i^{lt} = pR_h + (1-p)F_h + (\gamma - \xi_i)f_h$ , and her payoff is

$$V_i^{lt} = y_i^{lt} c'^{-1}(y_i^{lt}) - c(c'^{-1}(y_i^{lt})) - x_{i,l} \left( p(R_h - R_l) + (y_i^{lt} - pR_h) \left( 1 - \frac{q_l}{q_h} \right) \right). \quad (14)$$

(iii) If an intermediary issues short-term safe debt, in negative-news stage it optimally repays  $\Delta a_i = -\frac{a_i q_h - (x_{i,h} q_h + x_{i,l} q_l) f_h}{q_h - f_h}$  and trades  $\Delta x_{i,h} = \frac{x_{i,h} f_h + x_{i,l} q_l - a_i}{q_h - f_h}$ ,  $\Delta x_{i,l} = -x_l$ . These actions lead to continuation value  $v^{st} = \frac{F_h - f_h}{q_h - f_h} (x_{i,h} q_h + x_{i,l} q_l - a_i)$ . At  $t = 0$ , the manager faces constraints  $a_i \leq x_{i,h} q_h + x_{i,l} q_l$ ,  $(x_{i,h} + x_{i,l} \frac{q_l}{q_h}) f_h \leq a_i$ , with shadow prices  $\eta_i^{st} = \max\{\gamma - \xi_i - (1-p) \frac{F_h - f_h}{q_h - f_h}, 0\}$  and  $\varphi_i^{st} = \max\{(1-p) \frac{F_h - f_h}{q_h - f_h} - (\gamma - \xi_i), 0\}$ , respectively. When  $\eta_i^{st} > 0$ , her marginal payoff from originating risky loans is  $y_i^{st} = pR_h + (1-p + \gamma - \xi_i)q_h$ , and her payoff is

$$V_i^{st} = y_i^{st} c'^{-1}(y_i^{st}) - c(c'^{-1}(y_i^{st})) - x_{i,l} \left( p(R_h - R_l) + (y_i^{st} - pR_h) \left( 1 - \frac{q_l}{q_h} \right) \right). \quad (15)$$

The following observations indicate a pecking order among these liability types. First,  $q_h \in (f_h, f_h^+]$  implies  $\frac{F_h - f_h}{q_h - f_h} - (\frac{q_h F_l}{q_l f_h} - \frac{F_h}{f_h}) = -\frac{q_h(q_h - f_h^+)}{(q_h - f_h)q_l f_h} \geq 0$ , which further implies  $\eta_i^{lt} \geq \eta_i^{st}$ . Second,  $y_i^{lt} = y_i^e + \eta_i^{lt} f_h$  when  $\eta_i^{lt} > 0$ , and  $y_i^{st} = y_i^{lt} + \eta_i^{st}(q_h - f_h)$  when  $\eta_i^{st} > 0$ , so  $y_i^e < y_i^{lt} < y_i^{st}$ . Third, manager payoff strictly increases in  $y_i$ :  $\frac{\partial V_i}{\partial y_i} = c'^{-1}(y_i) - x_{i,l}(1 - \frac{q_l}{q_h}) > c'^{-1}(pR_h + (1-p)F_h) - x_{i,l} > 0$ . Hence others equal, a manager issues short-term safe debt if  $\eta_i^{st} > 0$ , issues long-term safe debt if  $\eta_i^{lt} > \eta_i^{st} = 0$ , and issues only equity if  $\eta_i^{lt} = 0$ .

By monotonicity of  $\eta_i^{lt}$  and  $\eta_i^{st}$  in  $i$ , liability choices in each equilibrium are characterized by cutoffs. The uniqueness of these cutoffs are guaranteed by secondary market aggregate excess demand's monotonicity. Clearly,  $\eta_i^{lt}$  cannot be zero for all  $i$ , otherwise  $\Delta x_{i,l} > 0$  for all  $i$  and market does not clear unless  $\frac{q_l}{F_l} = \frac{q_h}{F_h}$ , but this equation contradicts  $\eta_i^{lt} = 0$ . Market-clearing condition (26) indicates that in equilibrium, outside investors only buy loans that have a (weakly) higher expected return. Possible equilibrium outcomes depend parameter values:

1.  $\eta_i^{st} = 0$  for all  $i$ , and there exists  $\lambda^{lt} \in (0, 1)$  such that  $\eta_i^{lt} > 0$  if and only if  $i \in [0, \lambda^{lt}]$ .

Equilibrium loan prices satisfy  $q_h \leq f_h + \frac{1}{\gamma}(1-p)(F_h - f_h)$ ,  $q_l \geq \frac{(1-p)F_l}{1-p+\kappa}$ , and  $\frac{q_l}{q_h} = \frac{(1-p)F_l}{(1-p)F_h + (\gamma - \xi_{\lambda^{st}})f_h}$ . No risky loan is sold to outside investors.

2. There exist  $\lambda^{st}, \lambda^{lt}$  such that  $0 < \lambda^{st} < \lambda^{lt} < 1$ ,  $\eta_i^{st} > 0$  if and only if  $i \in [0, \lambda^{st}]$ , and  $\eta_i^{lt} > \eta_i^{st} = 0$  if and only if  $i \in (\lambda^{st}, \lambda^{lt}]$ . Equilibrium loan prices satisfy  $q_h = f_h + \frac{(1-p)(F_h - f_h)}{\gamma - \xi_{\lambda^{st}}}$ ,  $q_l = \frac{(1-p)F_l}{1-p+\kappa}$ , and  $\frac{q_l}{q_h} = \frac{(1-p)F_l}{(1-p)F_h + (\gamma - \xi_{\lambda^{lt}})f_h}$ . In secondary market, long-term safe debt-financed intermediaries buy all high-quality loans sold by short-term safe debt-financed as equity-financed intermediaries. Low-quality loans are bought by equity-financed intermediaries and outside investors.
3.  $\eta_i^{lt} > 0$  for all  $i$ , and there exists  $\lambda^{st} \in (0, 1)$  such that  $\eta_i^{st} > 0$  if and only if  $i \in [0, \lambda^{st}]$ . Equilibrium loan prices satisfy  $q_h = f_h + \frac{(1-p)(F_h - f_h)}{\gamma - \xi_{\lambda^{st}}}$ ,  $q_l = \frac{(1-p)F_l}{1-p+\kappa}$ , and  $\frac{q_l}{q_h} > \frac{(1-p)F_l}{(1-p)F_h + (\gamma - 2\xi)f_h}$ . In secondary market, long-term safe debt-financed intermediaries buy all high-quality loans sold by short-term safe debt-financed intermediaries. All low-quality loans are bought by outside investors.
4.  $\eta_i^{st} > 0$  for all  $i$ . Equilibrium loan prices are  $q_j = \frac{(1-p)F_j}{1-p+\kappa}$ ,  $j = h, l$ . In secondary market, all risky loans are sold to outside investors.

**Case 3:**  $q_h \in (f_h^+, F_h]$ . In this case, long-term contract is strictly dominated because short-term contract maximizes ex-ante safe debt capacity ( $a_i \frac{q_h}{q_l} > a_i$ ), and  $\Delta a_i = -a_i$  is ex-post desirable. Since all safe debt-financed intermediaries will use short-term contract and that  $q_h > f_h^+$  implies  $\frac{q_l}{F_l} < \frac{q_h}{F_h}$ , optimal trades  $\Delta x_{i,h} = -x_{i,h}$  for all  $i \in \mathcal{I}$ . If outside investors buy loan  $h$ , their demand for loan  $l$ , which has a higher return, will be infinity. This contradicts with market clearing condition (26). So this case cannot exist in equilibrium.

**Proof of Proposition 5.** By lemma 2, the risk-neutral manager's objective in the negative-news stage trading problem (P1a) is increasing in  $\Delta x_{i,l}$ . If  $\rho < \frac{q_l}{q_h - q_l}$ , the manager's desired trade of loan  $l$  given constraint (OC) is  $\Delta x_{i,l} = (\frac{q_l}{q_h} - \rho)^{-1}(\hat{x}_{i,h} + \rho x_{i,l} - a_i - a_i^{oc})$ . Suppose this desired trade is feasible, the binding budget constraint implies that  $\Delta x_{i,h} = -\Delta x_{i,l} \frac{q_l}{q_h}$

and hence  $x_{i,h} + \Delta x_{i,h} = (1 - \rho \frac{q_h}{q_l})^{-1}(a_i + a_i^{oc} - \rho(x_{i,h} \frac{q_h}{q_l} + x_{i,l}) - \hat{e}_i)$ . So  $x_{i,h} + \Delta x_{i,h} \geq a_i$  holds with probability one if and only if  $a_i^{oc} \geq \rho((x_{i,h} - a_i) \frac{q_h}{q_l} + x_{i,l}) + \bar{e}$ . This lower bound of  $a_i^{oc}$  ensures that short-sale constraint of loan  $h$  is always satisfied:  $\Delta x_{i,h} = (1 - \rho \frac{q_h}{q_l})^{-1}(a_i + a_i^{oc} - \hat{x}_{i,h} - \rho x_{i,l}) \geq a_i - x_{i,h} + (1 - \rho \frac{q_h}{q_l})^{-1}(\bar{e} - \hat{e}_i) \geq -x_{i,h}$ . For the desired trade to be feasible, another short-sale constraint  $\Delta x_{i,l} \geq -x_{i,l}$  must be also satisfied, which is equivalent to  $a_i^{oc} \leq ((x_{i,h} - a_i) \frac{q_h}{q_l} + x_{i,l}) \frac{q_l}{q_h} + \hat{e}_i$ . This inequality always holds if and only if  $a_i^{oc} \leq ((x_{i,h} - a_i) \frac{q_h}{q_l} + x_{i,l}) \frac{q_l}{q_h}$ .

Note that this modified contract implements debt safety only if  $\rho < \frac{q_l}{q_h}$ ; if  $\rho \geq \frac{q_l}{q_h}$  instead, the manager would be able to substitute all high-quality loans to low-quality loans without violating constraint (OC).

## B An Analysis of the Two-Type Case

Consider the simplest heterogenous case: managers have two types  $\xi_i \in \{\underline{\xi}, \bar{\xi}\}$ , where  $0 \leq \underline{\xi} < \bar{\xi} < \gamma$ . The two types have exogenous population mass  $\alpha \in (0, 1)$  and  $1 - \alpha$ , respectively. In this case, constraints on safe debt choices must bind for at least one type. This is because the two types face the same cost (or profit) of portfolio substitution but enjoy different benefits from safe debt issuance. Market clearing, and hence allocations, depend on fraction  $\alpha$ . To illustrate the inefficiency in this case, the following result focuses on a subset of  $\alpha$  values before the complete analysis of the two-type case. For notational convenience, I use  $(\underline{x}^{CE}, \bar{x}^{CE}, \underline{a}_i^{CE}, \bar{a}_i^{CE})$  and  $(\underline{x}^{SP}, \bar{x}^{SP}, \underline{a}_i^{SP}, \bar{a}_i^{SP})$  to denote the competitive and planned choices for the two types, respectively.<sup>52</sup>

**Proposition A.1.** *Suppose  $\xi_i \in \{\underline{\xi}, \bar{\xi}\}$ ,  $\underline{x}^{CE} = \underline{x}^{SP}$  for any  $\alpha \in (0, 1)$ . When  $\alpha \in (\underline{\alpha}^{CE}, \bar{\alpha}^{SP})$  for endogenous cutoffs  $0 < \underline{\alpha}^{CE} < \bar{\alpha}^{SP} < 1$ ,  $\underline{a}^{CE} < \underline{a}^{SP} = x_{i,h} + x_{i,l}\pi$ ,  $\bar{a}^{CE} = \bar{a}^{SP} = 0$ . Competitive allocation is constrained inefficient:  $\bar{x}^{CE} < \bar{x}^{SP}$ , and  $A^{CE} < A^{SP}$ .*

<sup>52</sup>I include subscript  $i$  for choices of  $a_i$  because these choices depend on idiosyncratic quality shocks  $\tilde{x}_{i,l}$ .



*Proof.* In both competitive and planned allocations, the exogenous fraction  $\alpha \in (0, 1)$  determines which type(s) faces a binding constraint on the choice of  $a_i$ . There are three possibilities. For each possibility, allocation results follow respectively from Kuhn-Tucker conditions (6)–(8) and (11)–(13) and the market clearing condition. Figure A.1 summarizes these results. There are four endogenous cutoffs,  $0 < \underline{\alpha}^{SP} < \underline{\alpha}^{CE} < \bar{\alpha}^{SP} < \bar{\alpha}^{CE} < 1$ , that divide  $(0, 1)$  into five mutually exclusive regions. Prices and allocations are different across regions. For convenience, I define  $(\underline{x}, \bar{x}) := (c'^{-1}(pR + 1 - p + \gamma - \underline{\xi}), c'^{-1}(pR + 1 - p + \gamma - \bar{\xi}))$ .

**Both types bind:** For the competitive market, this implies  $\frac{(1-p)\pi}{1-p+\gamma-\underline{\xi}} < \frac{q_l}{q_h} < \frac{(1-p)\pi}{1-p+\gamma-\bar{\xi}}$ ,  $(\underline{x}^{CE}, \bar{x}^{CE}) = (\underline{x}, c'^{-1}(pR + (1-p)\pi\frac{q_h}{q_l}))$ , and  $(\underline{a}_i^{CE}, \bar{a}_i^{CE}) = (x_{i,h} + x_{i,l}\frac{q_l}{q_h}, 0)$ . Secondary market demand and supply for  $h$  are  $\alpha x_L \frac{q_l}{q_h}$  and  $(1-\alpha)(\bar{x} - x_L)$ . Market clearing requires  $\alpha \in (\underline{\alpha}^{CE}, \bar{\alpha}^{CE})$ , where  $\underline{\alpha}^{CE} := (\bar{x} - x_L)(\bar{x} - (1 - \frac{(1-p)\pi}{1-p+\gamma-\bar{\xi}}x_L))^{-1}$  and  $\bar{\alpha}^{CE} := (\underline{x} - x_L)(\underline{x} - (1 - \frac{(1-p)\pi}{1-p+\gamma-\underline{\xi}}x_L))^{-1}$ . For the planner, both types binding implies  $(\underline{x}^{SP}, \bar{x}^{SP}) = (\underline{x}, c'^{-1}(pR + 1 - p + \psi^{SP}))$  and  $(\underline{a}_i^{SP}, \bar{a}_i^{SP}) = (x_{i,h} + x_{i,l}\pi, 0)$ . Note that  $\gamma - \bar{\xi} < \psi^{SP} < \gamma - \underline{\xi}$ , so secondary market clearing requires  $\alpha \in (\underline{\alpha}^{SP}, \bar{\alpha}^{SP})$ , where  $\underline{\alpha}^{SP} := (\bar{x} - x_L)(\bar{x} - (1 - \pi)x_L)^{-1}$  and  $\bar{\alpha}^{SP} := (\underline{x} - x_L)(\underline{x} - (1 - \pi)x_L)^{-1}$ .

**Type  $\underline{\xi}$  slack:** For the competitive market, this implies  $\frac{q_l}{q_h} = \frac{(1-p)\pi}{1-p+\gamma-\underline{\xi}}$ ,  $(\underline{x}^{CE}, \bar{x}^{CE}) = (\underline{x}, \bar{x})$ , and  $\underline{a}_i^{CE} = x_{i,h} + x_{i,l}\frac{q_l}{q_h}$ ,  $\bar{a}_i^{CE} \in [0, x_{i,h} + x_{i,l}\frac{q_l}{q_h}]$ . Secondary market demand and supply for  $h$  are  $\alpha x_L \frac{q_l}{q_h}$  and  $(1-\alpha)(\bar{x} - x_L) - \int_{\alpha}^1 \bar{a}_i^{CE} di$ . Market clearing requires the demand to be no less than the supply when  $\bar{a}_i^{CE} = 0, \forall i \in [\alpha, 1]$ , which is equivalent to  $\alpha \leq \underline{\alpha}^{CE}$ . For the planner, type  $\underline{\xi}$  slack implies  $(\underline{x}^{SP}, \bar{x}^{SP}) = (\underline{x}, \bar{x})$ , and  $\underline{a}_i^{SP} = x_{i,h} + x_{i,l}\pi$ ,  $\bar{a}_i^{SP} \in [0, x_{i,h} + x_{i,l}\pi]$ . Similarly, market clearing requires  $\alpha \leq \underline{\alpha}^{SP}$ .

**Type  $\bar{\xi}$  slack:** For the competitive market, this implies  $\frac{q_l}{q_h} = \frac{(1-p)\pi}{1-p+\gamma-\bar{\xi}}$ ,  $(\underline{x}^{CE}, \bar{x}^{CE}) = (\underline{x}, \underline{x})$ , and  $\underline{a}_i^{CE} \in [0, x_{i,h} + x_{i,l}\frac{q_l}{q_h}]$ ,  $\bar{a}_i^{CE} = 0$ . Secondary market demand and supply for  $h$  are  $\int_0^{\alpha} \underline{a}_i^{CE} di - \alpha(\underline{x} - x_L)$  and  $(1-\alpha)(\underline{x} - x_L)$ . Market clearing requires the demand to be no less than the supply when  $\underline{a}_i^{CE} = x_{i,h} + x_{i,l}\frac{q_l}{q_h}, \forall i \in [\alpha, 1]$ , which is equivalent to  $\alpha \geq \bar{\alpha}^{CE}$ . For the planner, type  $\bar{\xi}$  slack implies  $(\underline{x}^{SP}, \bar{x}^{SP}) = (\underline{x}, \underline{x})$ , and  $\underline{a}_i^{SP} \in [0, x_{i,h} + x_{i,l}\pi]$ ,  $\bar{a}_i^{SP} = 0$ .

Similarly, market clearing requires  $\alpha \geq \bar{\alpha}^{SP}$ .

Clearly,  $\underline{x}^{CE} = \underline{x}^{SP} = \underline{x}$  for any  $\alpha$ . When  $\alpha \leq \underline{\alpha}^{SP}$  or  $\alpha \geq \bar{\alpha}^{CE}$ , investment choices are identical in competitive and planned allocations, so  $A^{CE} = A^{SP}$  by equation (14).<sup>53</sup> The result that  $\bar{x}^{CE} < \bar{x}^{SP}$  and  $A^{CE} < A^{SP}$  when  $\alpha \in (\underline{\alpha}^{SP}, \underline{\alpha}^{CE})$  follows from the following observations. When  $\underline{\alpha}^{SP} < \alpha \leq \underline{\alpha}^{CE}$ ,  $\psi^{SP} > \gamma - \bar{\xi}$  implies  $\bar{x}^{CE} < \bar{x}^{SP}$ ; When  $\underline{\alpha}^{CE} < \alpha \leq \bar{\alpha}^{SP}$ ,  $\underline{a}_i^{CE} < \underline{a}_i^{SP}$  and  $\bar{a}_i^{CE} = \bar{a}_i^{SP}$ ; When  $\bar{\alpha}^{SP} < \alpha \leq \bar{\alpha}^{SP}$ ,  $(1-p)\pi^{\frac{q_h}{q_l}} < 1-p+\gamma-\underline{\xi}$  implies  $\bar{x}^{CE} < \bar{x}^{SP}$ .  $\square$

Unlike the homogenous-manager case, the pecuniary externality may cause inefficiency when managers are heterogenous. In equilibrium, the price ratio tightens the low-cost type's binding collateral constraints, preventing these managers from issuing socially optimal quantities of safe debt. Behind the direct impact of loan prices, the inefficiency is driven by a deficiency of aggregate collateral. While the low-cost type's investment level is socially efficient, high-cost managers fail to fully internalize the social benefits of additional good loans and thus underinvest. This is because their private profits from selling good loans,  $(1-p)(\pi^{\frac{q_h}{q_l}} - 1)$ , are lower than the social benefits of collateral  $\psi^{SP} = \gamma - \underline{\xi}$ . Hence, this market's unique separation of debt issuance and collateral origination leads to an underproduction of safe assets. In this case, the regulator can correct the inefficiency by inducing equity-financed intermediaries to invest at the socially optimal level.

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<sup>53</sup>The intuition for this result is similar to that of lemma 3: when constraints are slack for both individual managers and the planner, the pecuniary externality does not affect the efficiency of allocation.

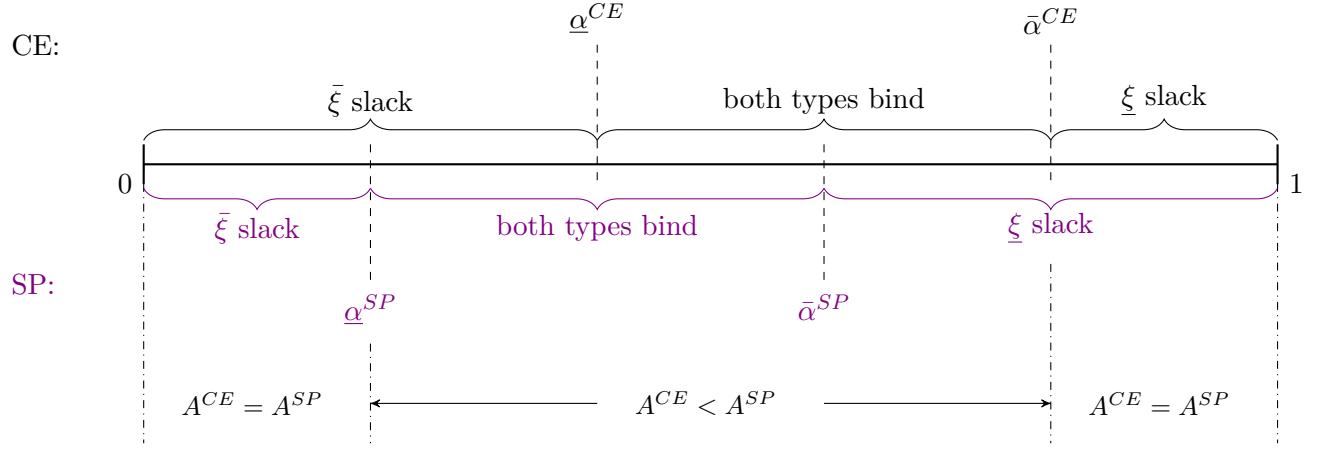


Figure A.1: **Two-type case: competitive and planned allocations.**

This figure illustrates how the competitive and planned allocations in the two-type case depend on  $\alpha \in (0, 1)$ , the fraction of low-cost manager type.

## C Data and Sample Construction

### C.1 Data and Sample

The main data used in this study come from Creditflux CLO-i, a database compiled from CLO trustee bank reports. This database provides information on CLO tranches, portfolio loan holdings, loan trades, and collateral test results. To examine safe debt-financed intermediaries' balance sheets, I construct a quarterly panel sample based on the most recent reports of a CLO by the end of each quarter. I include a CLO-quarter pair if information on the CLO's liabilities is nonmissing, and if its portfolio includes at least 50 leveraged loans and has at least \$50 million total par value. This filter leads to 13,825 quarterly observations for US CLOs between 2010–2019.

To investigate secondary market interactions in response to the arrival of a negative macroeconomic shock, I construct a cross-sectional sample that tracks the changes in CLO

loan portfolios between February 15 – June 30 of 2020. This sample includes all US CLOs that are issued before year 2020. For each CLO, I use the last portfolio snapshot available between January 1 – February 14, 2020 as the observation for a “pre” period, and I use the first snapshot available between July 1 – August 15, 2020 for a “post” period.<sup>54</sup> To measure secondary market prices at the trough, I also use the last snapshot between March 15–April 15, 2020 as the observation for the “mid” period. To alleviate measurement errors, I winsorize prices at the 1% and 99% percentiles.

Complementary databases include CRSP mutual fund portfolio holdings, Mergent Fixed Income Securities Database (FISD), Morningstar, and the SEC’s Form ADV. Panel A of Table 3 provides summary statistics of the panel sample. On average, a CLO has \$435 million principal outstanding and a portfolio consisting of 222 loans. CLOs in the sample are overall young with an average age of 4.2 years. For most CLOs, 60% to 75% of liabilities are AAA-rated tranches.

## C.2 Cleaning CLO datasets

Creditflux CLO-i database collects information about individual CLOs from trustee reports. In this database, each CLO is identified by a unique deal ID, and each of the CLO’s liability tranches is uniquely identified by a tranche ID. Unlike regulated institutions (e.g., banks and mutual funds), CLO trustee reports do not have fixed scheduled dates, and report dates are usually not at the end of a certain period. In the database, 75% of CLO–month pairs have at least one report available.

**Liabilities.** I begin with all US CLO deals that are issued in US dollars and have a non-missing closing date (i.e., the date when a CLO comes into legal existence) between

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<sup>54</sup>CLO trustee reports do not have any uniform report dates, and the time windows are used to select snapshots that are informative about CLO portfolios before and after the shock. My findings are insensitive to different choices of time windows.

2000–2020. There are 2,306 unique CLOs, 21,970 unique tranches, and 82,447 deal-level reports, and 612,689 tranche-level reports in total. These reports provide information on original and current amount of liability outstanding at the tranche level, and the asset manager company. To determine the seniority of a tranche, I first use the seniority name variable, and use original credit rating whenever this variable is missing. I hand match CLO manager company names to the filing number in the SEC’s Form ADV database and use this number as a unique manager identifier.

**Portfolio holdings.** The holdings dataset provides information on the borrower, loan facility type, interest rate, balance held in the portfolio, credit rating, maturity date, and Moody’s industry classification for each loan in a CLO’s portfolio snapshot. For years after 2017, a trustee-reported market price for each holding is also available. An important data limitation is that there is no loan-level unique identifier. While the holdings dataset provides issuer names and issuer IDs, a substantial fraction of these two variables are incorrectly assigned. Moreover, as different CLO managers prepare reports independently and most borrowers are private companies, a borrower might appear with different names in different reports. To mitigate the impact of inaccurate data on inferences for tests using the COVID-19 cross sectional sample, I carefully compare the name of every leverage loan borrower during 2016–2019 with the issuer names in CLO holdings data and manually correct 1,297 issuers that have mismatched names or (and) IDs.<sup>55</sup> I also replace a loan’s interest rate to be missing if the reported value is zero. After correcting these data errors, I eliminate duplicate records at the deal ID–report date–borrower–maturity date–balance amount level and aggregate balance amount to the deal ID–report date–borrower–maturity date level.<sup>56</sup> After this cleaning procedure, the holding dataset includes 22.3 million holding records.

**Loan trades.** For each loan trade, the transactions raw dataset provides information on

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<sup>55</sup>When different names of the same firm are reported, I check each borrower’s historical names, business names, nicknames, acquisition target names, and wholly-owned financing subsidiary names, and ensure that the same issuer ID is applied.

<sup>56</sup>These duplicates are generated when the data vendor scrap data from original trustee reports.

the direction (buy or sell), face amount of the loan, transaction price, and date of the trade. After removing duplicate records, I map loan trade records to CLOs using deal report ID.

**Collateral tests.** The raw dataset for collateral tests provides information on the name, current score, threshold score, and date of a test. I determine a test record as an over-collateralization test if the test name includes keywords “OC”, “O/C”, or “overcollateral”. Among OC tests, I further determine a record as a test for a senior tranche if the test name contains keywords “Class A”, “Senior”, “A ”, “A/B OC”, or “AB OC”. This procedure selects all senior OC thresholds and test scores, but cannot accurately identify the thresholds for the most senior (AAA) tranches. Any zero-valued threshold or test score is treated as missing. If the current threshold is missing or zero, I use original threshold score instead. For a few cases where a deal has multiple test scores for senior tranches, I use the lowest nonmissing score to mitigate the impact of data errors.

**Currency conversion.** CLO tranches and portfolio loan holdings denominated in Euro are converted into US dollar based on the current USD-EUR exchange rate.

### C.3 Counterfactual portfolios

I construct counterfactual static CLO portfolios by tracking loan holdings before the COVID-19 shock hits the US market. Consistent with the natural-experiment sample, the static portfolio is based on the last portfolio snapshot reported between January 1 and February 15, 2020 (“pre period”). To generate a counterfactual observation for each loan, I begin with a large set of portfolio holdings that consist of every CLO’s first portfolio snapshot reported between July 1 and August 15, 2020 (“post period”). Since there is no loan-level unique identifier available, I identify individual loans by a pair of issuer ID and maturity date.<sup>57</sup> I then calculate ex-post credit rating (coupon rate) for an ex-ante loan holding as the

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<sup>57</sup>To address that reported maturity dates for the same loan sometimes varies moderately across different CLOs’ portfolio reports, I use the quarter of reported maturity.

value-weighted average rating (coupon rate) across all CLOs’ ex-post matched holdings.<sup>58</sup> Merging ex-post information to the pre snapshots allows me to track changes in credit ratings and coupon rates for more than 94% of ex-ante loan holdings. To mitigate data errors introduced in this procedure, I use only portfolios for which at least 90% of pre-period holdings are tracked in counterfactual static portfolios (97% of the sample).

## D Supplementary Results, Figures, and Tables

### D.1 CLO Issuance

Figure A.2 shows annual CLO issuance. The pre-crisis issuance volume dropped to almost zero in 2009 and bounced back in 2012. In each of recent years, roughly 100 unique asset managers issued 200–300 new CLO deals in total, whose aggregate size is around \$150 billion.

### D.2 Interdependence of Portfolio Choice and Safe Debt Financing

In my model, asset managers’ financing choices lead to a positive cross-sectional relationship between an intermediary’s capital structure and the quality of its loan portfolio. It is trivial that loans of better quality secure more debt; However, as CLO managers optimally exhaust safe debt capacity, the model predicts a strong positive correlation between portfolio quality and safe debt outstanding. This endogenous relationship arises from optimal joint choices of portfolio and safe debt financing, which are commonly driven by unobserved securitization costs. I estimate this relationship in the cross section of CLOs by estimating panel regression

$$Quality_{it} = \beta AAA\%_i + \Gamma' Control_{it} + \delta_t + \epsilon_{it}, \quad (16)$$

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<sup>58</sup>A data limitation of this approach is that two loans issued by the same borrower and have the same maturity date would not be distinguished.

where the dependent variable is collateral quality measured using either portfolio value-weighted average loan rating or coupon rate. The variable of interest,  $AAA\%_i$ , is a CLO's AAA-rated tranche size as a fraction of total size of the deal. All specifications include year-quarter fixed effects  $\delta_t$ , thereby estimating  $\beta$  using only cross-sectional variation. This accounts for the impact of time-varying market conditions on overall leveraged loan quality.

Panel B of Table 3 presents summary statistics, and Table 4 reports the estimation results. Across specifications, the point estimates  $\hat{\beta}$  are both statistically and economically significant. Column (1) indicates that a CLO with a 10% larger AAA tranche on average holds a loan portfolio with 0.17 notch higher credit rating. Controlling for CLO size and age, as in column (2), the estimate becomes moderately larger. In column (3), I also include CLO cohort fixed effects that absorb any persistent balance sheet heterogeneity induced by different timings of CLO issuance.<sup>59</sup> The point estimate remains similar, suggesting that the result is not driven by unobserved shocks during the quarter of CLO issuance.

Columns (4)–(6) replace the dependent variable with portfolio value-weighted average coupon rate, which measures loan quality based on market risk pricing rather than rating agencies' models. Since leveraged loan coupons are quarterly updated based on a floating benchmark rate (typically 3-month LIBOR), in the cross section, a higher coupon implies a riskier portfolio. For both measures, an interquartile variation in  $AAA\%$  is associated with roughly 0.5 standard deviation higher collateral quality, suggesting a strong positive relationship between portfolio quality and safe debt outstanding.<sup>60</sup>

### D.3 Estimating the Effect of Risk Retention

Identifying and estimating the US Credit Risk Retention Rule's effect on CLO entry is challenging. First, the policy was imposed on the entirety of CLOs issued during its effective

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<sup>59</sup>CLO age is absorbed by the two groups of fixed effects in columns (3) and (6).

<sup>60</sup>After partialling out time fixed effects, the standard deviation of coupon rate is 0.48%.



period, making it difficult to find a control group. Second, the policy was introduced soon after the crisis and then revoked shortly, leaving us with very limited time-series variations for statistical inference. As an attempt to quantify the effect, I estimate panel regression

$$Entry_{imt} = \beta_0 + \beta_1 USmkt_{im} \times CRR_t + \beta_2 USmkt_{im} + \beta_3 CRR_t + \Gamma' Control_{m,t-1} + \epsilon_{imt}, \quad (17)$$

where every observation is an asset manager–market–year during 2013–2019.  $USmkt_{im}$  is an indicator variable that equals one (zero) for any manager  $i$  if market  $m$  is US (Europe).  $CRR_t$  is an indicator variable that equals one for 2015–2017, during which the Credit Risk Retention Rule affects the US market. I control for lagged growth rates of government debt and total bank deposits in either market as proxies for the supply of major safe assets. The identification of parameter  $\beta_1$  is based on an assumption that the entry rate in the US market would have evolved similarly as in the European market in the absence of the policy.<sup>61</sup>

Panel B of Table 3 presents summary statistics for this sample, and Table 5 reports the estimation results. Columns (1) and (4) indicate that the policy reduces the number and size of CLO entry by 0.3 and \$130 million, respectively. In column (2), the magnitude is similar for entry count after controlling for safe asset supply, and the magnitude becomes greater for the size of entry in column (5). In columns (3) and (6), I further include interaction terms with an indicator variable that equals one if the asset manager’s CLO AUM in year 2014 is above median. The triple-interacted term’s coefficient is statistically indistinguishable from zero, suggesting that the absolute effect of regulation has similar magnitudes on smaller and larger managers. As smaller managers’ pre-treatment levels of outcome variables are substantially smaller larger managers’, this indicates a greater relative impact on smaller managers’ business. Overall, the regulation causes an economically large reduction in CLO entry: the magnitudes are roughly 40% of unconditional averages.

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<sup>61</sup>While this is admittedly a strong assumption that is unlikely to hold exactly, I argue that estimates tend to understate true magnitude of the effect and thus provide useful lower bounds. This is because, first, without any intervention during 2000–2007, the European market grew slower, and second, the regulation was already imposed on the European market, making it a even slower-growing benchmark.



Figure A.2: **Annual CLO issuance, 2000–2019.**

This figure plots annual issuance amount and the numbers of deals and asset managers of open-market CLOs issued in the US and Europe. The issuance amount is decomposed by CLO liability tranches based on initial credit ratings, and tranche size denominated in Euros are converted to USD using exchange rate at issuance date. “Others” include mixed tranches and other non-rated tranches. Data come from Creditflux CLO-i database.



Figure A.3: **Intermediaries in the leveraged loan market, 2012–2020.**

This figure provides more detailed information on the composition of intermediaries in the leveraged loan market. The stacked bars plot total values of leveraged loans held by open-end mutual funds and hedge funds (left axis). The connected lines show market shares of leveraged loans outstanding (right axis), decomposed into collateralized loan obligations, public funds (open-end and close-end mutual funds and ETFs), and other intermediaries. Data come from Financial Accounts of the United States and Refinitiv LPC.

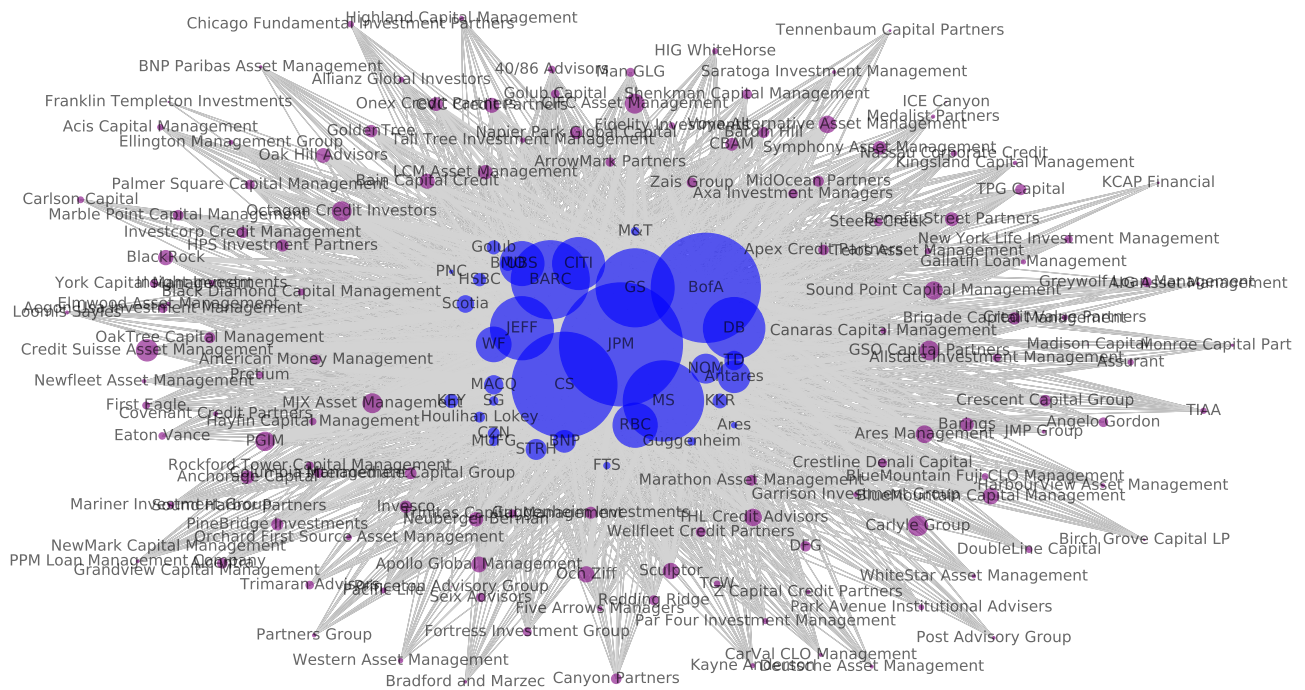
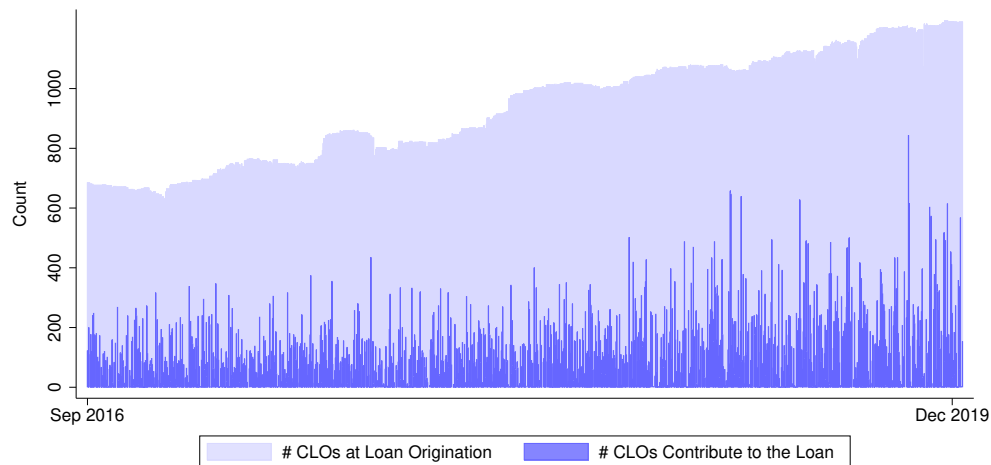
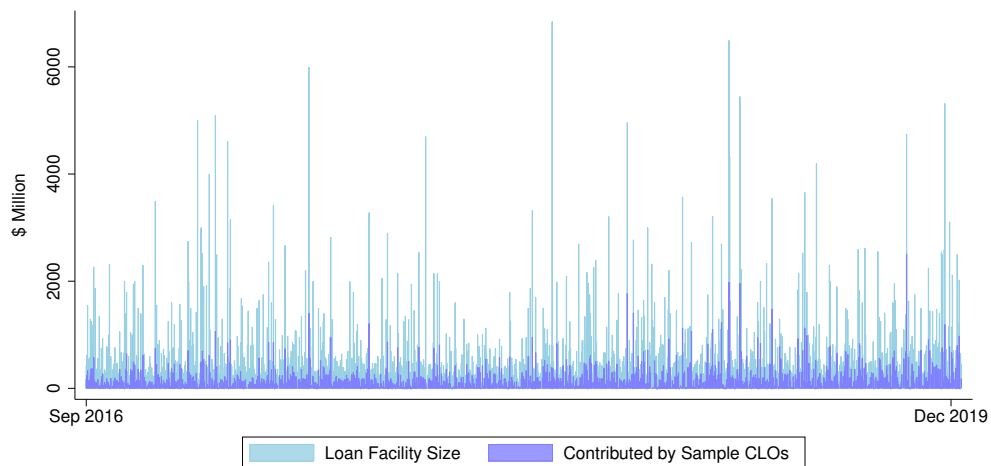


Figure A.4: Leveraged loan underwriters and CLO managers.

This figure plots underwriter banks (“lead arranger”) and CLO managers between 2016–2019. The size of a blue circle is proportional to the total amount of loans arranged by an underwriter, and the size of a purple circle is proportional to the total amount of loans purchased by a CLO manager. The width of each gray line connecting a lead arranger and a CLO manager represents the total amount of loan sale between the two institutions.



(a) Extensive Margin



(b) Intensive Margin

### Figure A.5: CLO primary market participation.

This figure presents CLO participation in leveraged loan primary market, as reflected in portfolio reports shortly after the syndication completion. Each vertical bar represents a loan facility. Panel (a) shows the number of CLOs observed at the end of syndication, and the number of CLOs that contribute to the loan. Panel (b) shows the size the each loan and the amount contributed by sample CLOs.



Figure A.6: **Vulnerable industry exposure and counterfactual collateral quality deterioration.**

This figure is a scatter plot that groups CLOs into 100 bins by portfolio weight in industries vulnerable to the COVID-19 pandemic before February 15, 2020 and depict the average counterfactual portfolio value-weighted average credit rating change between February 15 and June 30, 2020 within each bin. The definition of vulnerable industries follows [Foley-Fisher, Gorton, and Verani \(2020\)](#): Automotive, Consumer goods: Durable, Energy: Oil & Gas, Hotel, Gaming & Leisure, Retail, Transportation: Cargo, and Transportation: Consumer.

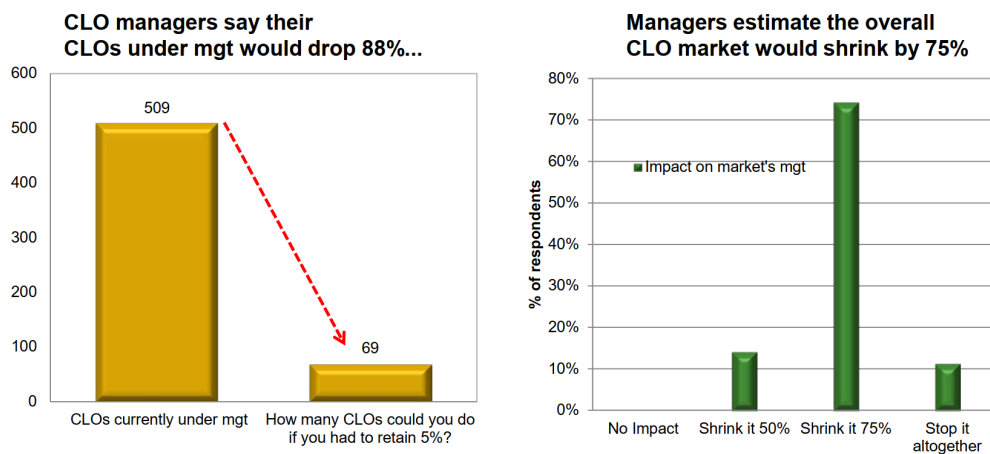


Figure A.7: **CLO equity IRR.**

This figure plots empirical distributions of US CLO equity tranche internal rate of return (IRR) by the deal's age. The vertical dashed line indicates the typical hurdle rate, 12%, maintaining a deal's IRR above which allows the asset manager to receive 20% of incentive fee from equity dividends.



(a) LSTA Lobbying by Year



(b) Asset Manager Survey, 2013

### Figure A.8: Industry response to CLO Risk Retention.

Panel A.8a of his figure shows the Loan Syndication and Trading Association's (LSTA) annual lobbying spending (Source: Center for Responsive Politics). Panel A.8b shows the result of LSTA 2013 survey on asset managers' expectations on the impact of US CLO Credit Risk Retention on the market.



Table 1: **CLO Debt Maturity**

This table presents empirical distributions of CLO debt tranche maturity, measured in number of years. The sample includes US CLOs issued between 2010 and 2020.

Seniority	Mean	SD	p10	p25	p50	p75	p90	N
AAA	9.1	2.6	6	8	9	11	12	2,928
AA	9.8	2.4	7	9	10	12	13	2,238
A	10.2	2.5	7	9	10	12	13	2,194
BBB	11.1	2.7	8	10	12	12	14	2,051
BB	11.8	2.9	9	11	12	13	15	1,917
B	11.9	3.2	8	11	12	13	16	676
Total	10.4	2.9	7	9	11	12	13	12,004

Table 2: **Conversion from Letter Rating and Numerical Rating**

This table presents the conversion from letter ratings to numerical ratings, for credit ratings by Moody's and S&P. If only one rating agency's letter rating is available for a debt, the numerical rating is based on the available rating. If the two rating agencies' letter ratings convert to different numbers, the numerical rating is calculated as the average of the two converted numbers.

Letter Rating		Numeric Rating
Moody's	S&P	
Aaa–A3	AAA–A-	14
Baa1	BBB+	13
Baa2	BBB	12
Baa3	BBB-	11
Ba1	BB+	10
Ba2	BB	9
Ba3	BB-	8
B1	B+	7
B2	B	6
B3	B-	5
Caa1	CCC+	4
Caa2	CCC	3
Caa3	CCC-	2
Ca	CC, C	1
C	SD, D	0

Table 3: **Summary Statistics**

Panel A of this table presents summary statistics of the quarterly panel dataset for 2010–2019, where every observation is a US CLO’s most recent information reported by the end of a quarter. The size of a CLO is measured with the total par value of loan holdings (in USD million). *AAA%* is a CLO’s most senior debt tranche size divided by total liabilities as observed at its issuance. *Rating* and *Coupon* are par value-weighted averages of a CLO’s portfolio loan holdings’ current credit ratings and coupon rates (i.e., the sum of a floating benchmark rate and a fixed spread). Panel B presents summary statistics for an annual panel dataset that includes CLOs in both the US and European markets, where every observation is an asset manager–market–year between 2013–2019. *GovDebtGrowth* and *DepositGrowth* are respectively the growth rates of total government debt and bank deposits in either market. Details on sample construction and the conversion of letter ratings are provided in Appendix C.

	mean	sd	min	p10	p25	p50	p75	p90	max
<b>Panel A: CLO–quarter panel, 2010–2019</b>									
Observations:	13,825								
Size (\$mm)	435.4	194.2	50.1	213.4	334.1	417.7	508.3	623.8	3,067.4
Loans (count)	222.3	103.2	51	94	147	217	282	344	815
Age (year)	4.23	2.56	0.00	0.75	2.00	4.00	6.25	8.00	15.50
AAA%	0.68	0.07	0.44	0.61	0.64	0.67	0.74	0.76	0.83
Rating	6.77	0.38	2.51	6.37	6.61	6.79	6.97	7.17	8.39
Coupon (%)	4.91	0.84	0.04	3.80	4.23	4.92	5.60	5.92	8.91
<b>Panel B: asset manager–market–year panel, 2013–2019</b>									
Observations:	2,044								
Entry (count)	0.75	1.3	0	0	0	0	1	3	9
Entry (\$ mm)	586.7	1146.8	0.0	0.0	0.0	0.0	787.3	2,006.1	9,544.8
GovDebtGrowth (%)	3.9	2.0	1.4	1.9	2.1	3.6	5.6	7.2	8.0
DepositGrowth (%)	5.1	2.5	1.2	3.0	3.7	4.1	6.2	8.5	11.1

Table 4: **Safe Debt Financing and Portfolio Quality**

This table reports results from estimating panel regression

$$Quality_{it} = \beta AAA\%_i + \Gamma' Control_{it} + \delta_t + \epsilon_{it},$$

where every observation is a CLO-quarter pair measured based on the last portfolio snapshot available by the end of a quarter during 2010-2019. The dependent variable is a collateral quality measure. Regressor  $AAA\%_i$  is original size of CLO  $i$ 's AAA-rated debt tranche size divided by total size of the deal. In columns (1)–(3), collateral quality is measured with portfolio value-weighted average loan rating. The measure in columns (4)–(6) is value-weighted average loan interest rate (the sum of a fixed spread and a floating benchmark rate). Control variables, including natural logarithm of total par value of loan holdings and CLO age (in year), are measured at the date when portfolios are reported. Standard errors are clustered at the CLO deal level, and the t-statistics are reported in parentheses. \*, \*\*, \*\*\* represent 10%, 5%, and 1% levels of statistical significance.

	(1)	(2)	(3)	(4)	(5)	(6)
Dep. Var.	<i>Rating</i>			<i>Coupon</i>		
$AAA\%$	1.68*** (6.39)	1.88*** (6.66)	1.76*** (6.43)	−2.94*** (−8.06)	−2.25*** (−6.21)	−2.25*** (−6.10)
$\ln(\text{Size})$		0.07** (2.62)	0.06** (2.85)		0.14*** (2.37)	0.01 (0.28)
Age		−0.01 (−1.25)			−0.03*** (−4.74)	
Year-Quarter FEs	Y	Y	Y	Y	Y	Y
CLO Cohort FEs	N	N	Y	N	N	Y
Observations	13,825	13,825	13,823	13,825	13,825	13,823
R-squared	0.11	0.12	0.17	0.70	0.71	0.74

Table 5: **Credit Risk Retention and CLO Entry**

This table reports results from estimating panel regression

$$Entry_{imt} = \beta_0 + \beta_1 USmkt_{im} \times CRR_t + \beta_2 USmkt_{im} + \beta_3 CRR_t + \Gamma' Control_{m,t-1} + \epsilon_{imt},$$

where every observation is an asset manager–market–year between 2013–2019.  $USmkt_{im}$  is an indicator variable that equals one (zero) if market  $m$  is the US (Europe).  $CRR_t$  is an indicator variable that equals one for years that Credit Risk Retention Rule affects the US market. Control variables are lagged growth rates of total government debt and total deposit in market  $m$ . The dependent variable in columns (1)–(3) is manager  $i$ 's number of CLO issuance in market  $m$  and year  $t$ . In columns (4)–(6), the dependent variable is the total size (in \$ million) of manager  $i$ 's CLO issuance in market  $m$  and year  $t$ . In columns (3) and (6),  $LargeMgr$  is an indicator variable that equals one if the manager's total size of CLOs measured in year 2014 is above median. Standard errors are clustered at the manager-by-market level, and the t-statistics are reported in parentheses. \*, \*\*, \*\*\* represent 10%, 5%, and 1% levels of statistical significance.

Dep. Var.	(1)	(2)	(3)	(4)	(5)	(6)
	Entry Count			Entry Size (\$ mm)		
USmkt×CRR	−0.28*** (−5.01)	−0.31*** (−4.42)	−0.23*** (−3.53)	−130.58*** (−2.58)	−218.29*** (−3.28)	−184.19*** (−3.84)
USmkt×CRR×LargeMgr			−0.16 (−1.40)			−68.20 (−0.68)
USmkt	1.07*** (8.32)	1.37*** (8.54)	0.77*** (6.70)	829.96*** (7.55)	952.91*** (7.30)	414.14*** (5.73)
CRR	−0.06*** (−2.61)	−0.03 (−1.56)	−0.01 (−0.29)	−14.27 (−1.16)	−2.25 (−0.18)	3.10 (0.26)
LargeMgr			0.49*** (5.40)			353.61*** (4.83)
USmkt×LargeMgr			1.19*** (5.63)			1,077.55*** (6.00)
CRR×LargeMgr			−0.06 (−1.28)			−18.11 (−0.52)
Controls	N	Y	Y	N	Y	Y
Observations	2,044	2,044	2,044	2,044	2,044	2,044
R-squared	0.14	0.15	0.35	0.12	0.12	0.32