

# Safety Transformation and the Structure of the Financial System \*

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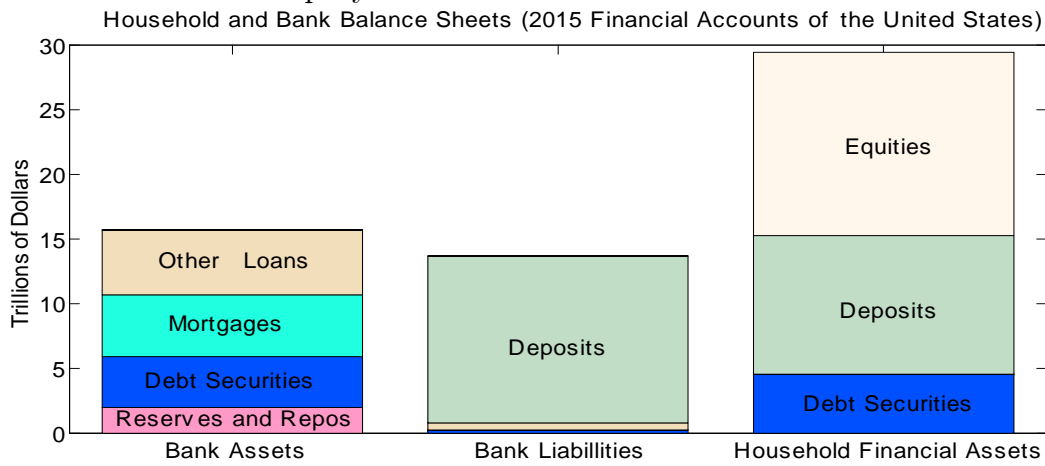
## Abstract

This paper develops a theory of financial intermediation in public securities markets. Riskless securities earn a convenience yield, and all firms face agency costs of equity financing. Intermediaries endogenously emerge to buy a low risk, diversified portfolio of debt securities, allowing intermediaries to issue many riskless deposits and little equity. The model explains the credit spread puzzle in bonds and low risk anomaly in stocks, why intermediary leverage is high and corporate leverage is low, why intermediaries own debt and households own equity, how safe asset demand fueled the subprime boom, and how quantitative easing effects output and financial stability.

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An important role of financial intermediaries is to issue safe, money-like assets, such as bank deposits and money market fund shares. As an empirical literature has documented (Krishnamurthy & Vissing-Jorgensen 2012, Nagel 2016, Sunderam 2015), these assets have a low rate of return, strictly below the risk-free rate they would earn without providing monetary services. Agents who can issue these assets therefore raise financing on attractive terms, capturing the "demand for safe assets" that pushes their cost of borrowing below that of others. As shown in (Gorton & Pennacchi 1990), any firm that can issue riskless securities meets the demand for safe, money-like assets. This raises the question of why financial intermediaries almost uniquely can issue such assets.



The assets owned by money-creating financial institutions are primarily loans and debt securities issued by firms, households, and governments. Of the \$17.3 trillion of assets owned by depository institutions in the USA in 2015, \$4.8 trillion were mortgages, \$3.9 were debt securities including \$2.1 trillion of agency and GSE backed securities, \$5.0 trillion were non-mortgage loans to firms and households, and \$2.0 trillion were reserves, while only \$100 billion were equities which are held primarily by households. While money creation in the "shadow banking" system is harder to measure, money market funds, securitization vehicles, and broker dealers that play a role here also invest significantly in debt.<sup>1</sup> The role of publicly traded debt and readily securitized mortgages in the asset portfolios of banks and shadow banks is not consistent with

<sup>1</sup>Another financial institution that can be said to issue long duration safe assets is a life insurance company, since life insurance contracts promise fixed dollar values in the future. The portfolios in the general account of life insurers which back insurance contracts are also composed almost entirely of debt.

many existing models that imply intermediaries hold special assets that are unavailable to other investors.<sup>2</sup>

This paper develops a general equilibrium model in which financial intermediaries emerge endogenously, buying a portfolio of publicly available debt securities to most effectively create safe, money-like assets. The model explains (i) why money-creating financial intermediaries invest in debt while households invest in equity, (ii) why intermediaries are highly levered while non-financial firms are not, and (iii) why risk is priced more expensively in the debt market than the equity market, consistent with the "credit spread puzzle" in bonds and "low risk anomaly" in stocks. In addition to its implications for the structure of the financial system, the model provides a framework for understanding the general equilibrium effect of changes in the supply and demand for safe assets. An increased demand for safe assets replicates many features of the subprime boom, with intermediaries expanding and taking more risk while the non-financial sector increases its leverage. Quantitative easing policies increase the supply of safe assets, decrease the price of risk in debt markets, reduce intermediary risk taking, and increase output at the zero lower bound.

Two basic ingredients are at the core of the model. First, households obtain utility directly from holding riskless assets, which captures the demand for money-like assets without modelling the frictions that make money essential (Stein 2012*b*). The idea that only safe assets function as money goes back at least to (Gorton & Pennacchi 1990), who show that risky assets are subject to a lemons problem when informed and uninformed agents trade. Second, all firms face an agency problem in financing risky investment. Each firm's management privately observes its output and reports this output to outside investors. If management underreports, it can divert some fraction of the difference between the true and reported output. This costly state falsification problem is due to (Lacker & Weinburg 1989) and implies that riskier investments face more severe agency frictions. The optimal strategy of a financial intermediary is to choose a low risk portfolio that backs as many riskless assets as possible while minimizing the agency costs due to the risk in its asset portfolio. High risk assets that would cause too severe of an agency problem for the intermediary are bought by households instead.

The model provides a new theory of the connection between a bank's assets and liabilities that is consistent with the role of publicly available securities on bank balance sheets. Existing theories that

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<sup>2</sup>Household portfolio holdings are based on the assumption that their mutual funds are 70% equity and 30% debt, consistent with data from the Investment Company Institute's Investment Company Fact Book. 37% of households' direct holdings of debt securities are municipal bonds where they face a tax advantage over other investors.

explain both the assets and liabilities of financial intermediaries imply that bank assets are too illiquid to ever sell to outsiders. (Diamond 1984, Diamond & Rajan 2001) argue that banks acquire information that makes their assets illiquid, while (Dang, Gorton, Holmstrom & Ordóñez 2017) requires banks to conceal information so that their assets cannot trade at a market price.<sup>3</sup> In my framework, banks have the same investment opportunities and information as households and face the same frictions in raising outside financing as other firms. The key connection between the assets and liabilities of banks in this paper is that a bank's asset portfolio should be low risk in order to back many riskless deposits with a minimum of agency costs. This explanation for the role of intermediaries in public securities markets connects financial intermediation theory with a literature on the role of intermediaries in the pricing of public securities (Krishnamurthy & He 2013, Adrian, Etula & Muir 2014) that has had some empirical success. While banks own some assets unavailable to households, this paper bridges the gap between financial intermediation theory and the large holdings of publicly available securities on intermediary balance sheets by studying a framework in which all financial assets are publicly available.<sup>4</sup>

The liquidity of bank balance sheets has increased over time due to the development of securitization and syndication, suggesting that this paper is most relevant for understanding the modern financial system. (Loutskina 2011, Loutskina & Strahan 2009) show a large secular increase in the liquidity of bank assets as they become easier to securitize and show that this mitigates their financial constraints. (Barnish, Miller & Rushmore 1997) argues that the rise of syndication has made the bank loan market more liquid. In addition, the role of securitized assets and other public securities in the shadow banking system seems to be particularly in tension with models that emphasize illiquid relationship lending. While existing literature (DeMarzo & Duffie 1999, DeMarzo 2005) studies the degree to which informed originators are able to sell securitizations to outsiders, these models do not explain why the stakes sold to outsiders are bought primarily by levered financial institutions who may not have private information.

In the model, a continuum of projects with exogenous output (Lucas trees) provide all resources and must be managed by firms.<sup>5</sup> Firms choose whether to buy a single tree or act as a financial intermediary

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<sup>3</sup>The branch of this literature that assumes bankers monitor borrowers implies that public equities are too informationally sensitive to be sold, while empirically non-expert households have large holdings of equity.

<sup>4</sup>A natural extension is to study a model in which assets are publicly available but may still be illiquid.

<sup>5</sup>As noted later, the model can be interpreted to also include trees that represent houses, which households can use as collateral to borrow from banks.

who can invest in securities. Each tree-owning non-financial firm sells securities whose payoffs must be increasing in its own cashflows and chooses to issue a low risk debt security and a high risk equity security.<sup>6</sup> These securities are exposed to both aggregate and tree-specific idiosyncratic risk, and this idiosyncratic risk ensures that non-financial debt cannot directly meet households' demand for riskless assets. This provides a role for intermediaries, who buy a diversified portfolio of non-financial debt which is safe enough to back a large quantity of riskless deposits with a small buffer of loss-bearing capital. Intermediaries do not buy riskier equities because the agency costs of doing so pushes their willingness to pay below that of households. As is true empirically, the balance sheet of an intermediary is composed of a pool of debt which it then tranches into a riskless deposit and risky equity. The fact that non-financial debt has low systematic risk allows the intermediary to be highly levered, consistent with (Berg & Gider forthcoming)'s empirical finding that the low asset risk of banks explains their high leverage.

The fact that intermediaries are willing to pay more than households for low systematic risk assets but less for high systematic risk assets implies that asset prices are segmented. The pricing kernel of assets owned by the intermediary features a low risk-free rate, since riskless assets can back deposits without any loss-bearing capital, but a high price of systematic risk, reflecting the intermediary's agency costs of holding a risky portfolio. As in models with leverage constraints (Frazzini & Pedersen 2014, Black 1972), less systematic assets therefore earn a higher risk-adjusted return than more systematic assets. The intermediary's ability to raise deposit financing gives it a low borrowing cost, so it exploits this segmentation by holding a low risk portfolio on a highly levered balance sheet.

This endogenous market segmentation is arbitrated by non-financial firms when they choose their capital structure, resulting in segmentation between debt and equity markets. Each firm chooses its leverage so that its debt is sufficiently low risk to sell to intermediaries and its equity is sufficiently high risk to sell to households. The firm's total market value is therefore strictly higher than any agent would be willing to pay for all of the firm's cashflows. When each firm chooses its capital structure optimally, all debt is low enough risk to be priced by the intermediary's pricing kernel and all equity is high enough risk to be priced by the household's pricing kernel. Thus, the segmentation between low and high risk assets

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<sup>6</sup>In practice, conglomerate firms such as Berkshire-Hathaway and General Electric do exist and are sometimes thought to play a role as financial intermediaries. A firm that could hold a diversified tree portfolio at a cost could also create safe assets in my model and compete with other intermediaries.

is endogenously segmentation between the debt and equity markets. This is consistent with the "credit spread puzzle" (Huang and Huang 2012) that structural credit models that infer credit spreads assuming the debt and equity markets are integrated tend to imply smaller spreads than empirically observed. It also explains the "low risk anomaly" (Black Jensen Scholes 1972, Baker Bradley Taliaferro 2014, Bansal Coleman 1996), which finds that the price of risk in the stock market is too low for simple measures of risk to be consistent with the empirically observed high return on the stock index and low risk-free rate.

Because the model endogenously determines intermediary and household balance sheets, financial and non-financial capital structure, and segmented pricing of debt and equity securities, it provides a rich framework for studying the financial system's response to changes in the supply and demand for safe assets. I use it to study the effects of a growing demand for safe assets, which a macroeconomic literature (Bernanke et. al. 2011, Caballero Farhi 2017) argues is a feature of the global economy in recent decades, and to understanding the effects of the quantitative easing policies that involved purchasing publicly available bonds. The model implies that an increased demand for safe assets induces the financial system to expand and invest in riskier debt, decreasing the borrowing costs of the non-financial sector, and induces the non-financial sector to increase its leverage. This is consistent with the subprime boom of the 2000s.

The model is a natural framework for studying how quantitative easing policies impact intermediary risk taking and non-financial leverage decisions. The fact that intermediaries hold public securities in my model allows it to speak to the effects of government purchases of public securities.<sup>7</sup> By swapping intermediaries' risky assets for riskless assets, quantitative easing reduces intermediary risk taking, compresses risk premia in debt markets, increases the supply of safe assets, and stimulates aggregate demand at the zero lower bound. The model also can be used to understand the policy speech (Stein 2012b) which argues that the reduced borrowing costs caused by quantitative easing leads firms to issue debt that weakens its effects. Away from the zero lower bound, a rise in the natural rate due to quantitative easing can increase borrowing costs. At the zero lower bound, borrowing costs decrease, but the increase in consumption also boosts the price of equities owned by households, consistent with event studies (Neely 2011, Chodorow-Reich 2014). Firms may delever in response to quantitative easing, since the cost of equity financing decreases.

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<sup>7</sup>There do exist models that simply assume assets purchased in quantitative easing can only be held by intermediaries. My model reconciles this literature with models where intermediaries appear endogenously.

# 1 Baseline Model

I summarize the model's agents, timing, and frictions. Next, I solve the portfolio choice problems of the representative household and intermediary in partial equilibrium, taking as given a set of securities available for purchase. I use these portfolio choice results to show that the market for low risk assets (which the intermediary buys) are segmented from the market for high risk assets (which the household buys). I then show how non-financial firms choose the securities they issue to take advantage of this segmented capital market. After characterizing the model's unique equilibrium, I use the model as a framework for showing how the financial system responds to changes in the supply and demand for safe assets and to quantitative easing policies.

**Setup** The model has two periods ( $t = 1, 2$ ). Goods  $C_1$  are available at time 1 which cannot be stored. Output at time 2 is produced by a continuum of trees indexed by  $i \in [0, 1]$ , where tree  $i$  produces  $f_i$ . At time 2, a binary aggregate shock is realized to be "good" or "bad" with probability  $\frac{1}{2}$ , and the output of the trees are conditionally independent given this aggregate shock. These aggregate and idiosyncratic shocks to each tree's output are the only sources of risk.

There are two classes of agents: households and firms. Households are endowed with wealth  $W_H$  which they invest in order to consume. The household maximizes its expected utility

$$u(c_1) + E[u(c_2)] + v(d). \tag{1}$$

which depends on its consumption  $(c_1, c_2)$  at times 1 and directly on its holding  $d$  of riskless assets that pay out at time 2. Households can invest in securities issued by firms, but trees must be held by firms.<sup>8</sup>

Firms can choose either to be an "intermediary" or a "non-financial firm." Each non-financial firm can invest in one tree  $i$  and sell securities backed by the tree. Firms are not able to invest in diversified pools, motivated by the idea that conglomerate firms can be difficult to manage. Intermediaries cannot invest in trees but can invest in the same financial securities available to households and can issue securities backed by their portfolio. Unlike non-financial firms, intermediaries can hold a diversified portfolio. An

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<sup>8</sup>Allowing some trees to be held by households (representing houses rather than corporate assets) would allow the model to have homeowners getting mortgages from banks with little added complexity as explained later on.

intermediary can invest in a diversified portfolio like a household and issue securities like a firm, allowing it to issue riskless assets backed by a pool of securities, which other agents cannot do.

The output of firms is not verifiable and must be reported by its management to outside investors. Management can underreport output to divert resources. If a firm has payoffs  $\delta_{firm}$  at period 2 and its management reports  $\delta'_{firm} < \delta_{firm}$  in the support of the firm's output distribution, management can divert resources  $C(\delta_{firm} - \delta'_{firm})$ , where  $C'(0) = 0$ ,  $C'' > 0$ , and  $\sup_e C'(e) < 1$ .  $C'(e) < 1$  implies that resources are destroyed when management diverts. The owners of the firm can provide the management with output-contingent compensation, and it is optimal to incentivize management not to divert. This agency problem is equivalent to the costly state falsification model of (Lacker Weinburg 1986). The problem makes it costly for a firm to own risky assets, since more asset risk increases the amount management can divert. This problem incentivizes the intermediary to choose a low risk portfolio, while it is an unavoidable cost for non-financial firms since the riskiness of each tree's output  $f_i$  is exogenous.<sup>9</sup>

Once management has reported the firm's output, the equityholders who control the firm can choose to either destroy output or raise additional funding.<sup>10</sup> Equityholders will destroy output if their residual claim is decreasing in the firm's output and will raise additional funding if their residual claim increases more than one for one in the firm's output. Following (Innes 1990), each firm will choose to issue securities that are increasing in its own cashflows so equityholders will not manipulate the firm's output. In addition, firms cannot issue securities whose payoffs depend on the uncontractible aggregate state or the output of other firms. Given these constraints, all firms optimally issue only debt and equity, so for simplicity the paper can be understood taking these securities as given and ignoring this second agency problem.

Financial securities are indexed by  $s \in [0, 1]$ . Each security  $s$  has payoff  $\delta_s$  at time 2 and is sold for a price  $p_s$  at time 1. These securities  $s \in [0, 1]$  are issued by the firms owning trees  $i \in [0, 1]$ . To relate the indexing of trees and securities, let  $s = \frac{i}{2}$  refer to the debt of the firm owning tree  $i \in [0, 1]$  and  $s = \frac{1}{2} + \frac{i}{2}$  refer to that firm's equity. All assets can be purchased by either the household or the intermediary.<sup>11</sup>

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<sup>9</sup>At the end of time 2, households can transfer utility directly to management to buy the consumption goods paid to them, preserving the tractability of an endowment economy.

<sup>10</sup>If the firm's owners raise hidden funding, they do so at time 2 and also pay back the loan at time 2 so that the market interest rate is 0 consistent with (Innes 1990).

<sup>11</sup>The continuum law of large numbers is assumed to hold. A portfolio of  $m(s)$  units of asset  $s$  pays  $\int_0^1 [E_{bad}\delta_s] m(s) ds$  in the bad state and  $\int_0^1 [E_{good}\delta_s] m(s) ds$  in the good state. A sufficient condition if  $\|m\|_\infty < \infty$  as required by the resource constraint is  $\sup_s \max(Var_{good}\delta_s, Var_{bad}\delta_s) < \infty$  which follows from  $\sup_i \max(E_{bad}f_i^2, E_{good}f_i^2) < \infty$ .



In this model, securities cannot be broken into Arrow-Debreu claims or be sold short. The expected payment of each security is positive in both states of the world. The ratio  $\frac{E_{good}\delta_s}{E_{bad}\delta_s}$  determines the exposure of security  $s$  to systematic risk, and agents can buy high or low systematic risk securities. However, it is impossible for an agent who wants only bad state payoffs to avoid buying good state claims as well. If agents were able to form long/short portfolios, they could go long assets for which  $\frac{E_{good}\delta_s}{E_{bad}\delta_s}$  is low and short assets for which  $\frac{E_{good}\delta_s}{E_{bad}\delta_s}$  is high to isolate bad state payoffs, so this is forbidden.

**Household's problem** The household faces a standard intertemporal consumption problem, except that it obtains utility directly from holding riskless assets. The household may either consume or invest in securities. Risky securities owned by the household are priced by the marginal utility of consumption they provide. The risk-free rate lies strictly below the rate implied by the household's consumption preferences, reflecting the extra utility benefit of holding riskless assets. An arbitrage trade which exploits this low risk-free rate is to buy a portfolio of assets and sell a riskless senior tranche and risky junior tranche backed by the portfolio, which is precisely the role played by intermediaries.

The household maximizes expected utility in expression 1 over period 1 consumption  $c_1$ , period 2 consumption  $c_2$ , and "deposits"  $d$ , which are riskless securities owned by the household.  $u$  and  $v$  are strictly increasing, strictly concave, twice continuously differentiable, and satisfy Inada conditions. The household's only choice is how to invest or consume its initial wealth  $W_H$ . It may purchase either riskless assets, which yield the direct benefit  $v(d)$  as well as a riskless cashflow at period 2, or other securities issued by the intermediary or non-financial firms. It cannot sell short or borrow to invest.

The household's problem is to maximize its expected utility given a deposit rate  $i_d$  and prices  $p_s$  of securities  $s$  which pay stochastic cashflows  $\delta_s$  in period 2. Given the rate  $i_d$ , the price of one deposit at time 1 is  $\frac{1}{1+i_d}$ . Consumption at period 2 is the sum of payoffs from deposits and securities  $c_2 = \int \delta_s q_H(s) ds + d$ , where  $q_H(s)$  is the quantity of security  $s$  purchased by the household.  $q_H(s)$  cannot be negative, since short selling is not allowed. The household's problem can be written as

$$\begin{aligned}
& \max_{d, q_H(\cdot), c_1} u(c_1) + E \left[ u \left( \int_0^1 \delta_s q_H(s) ds + d \right) \right] + v(d) & (2) \\
& \text{subject to } c_1 + \frac{d}{1+i_d} + \int_0^1 p_s q_H(s) ds = W_H \text{ (budget constraint),} \\
& q_H(\cdot) \geq 0 \text{ (short sale constraint)}
\end{aligned}$$

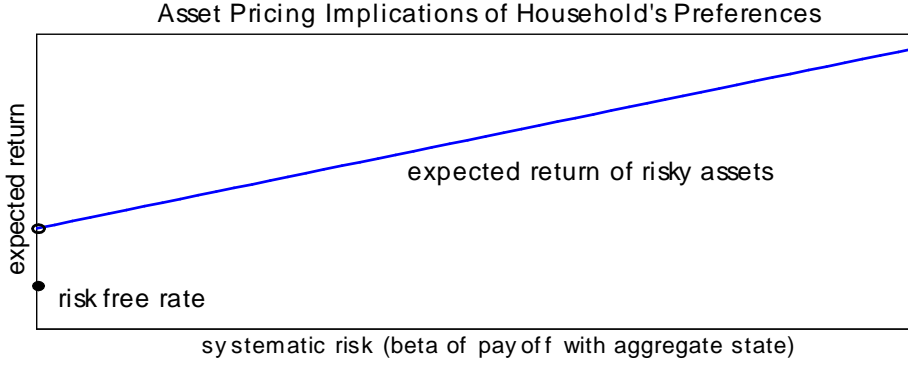
The first order conditions for deposits  $d$  (which has an interior solution since  $v'(0) = \infty$ ) and for the quantity  $q_H(s)$  to purchase of security  $s$  are

$$u'(c_1) = (1+i_d)(E[u'(c_2)] + v'(d)) \quad (3)$$

$$p_s \geq E \left[ \frac{u'(c_2)}{u'(c_1)} \delta_s \right] \quad (4)$$

where inequality 4 must be an equality if  $q_H(s) > 0$ .

Two features of the household's optimal investments are notable. First, inequality 4 implies that only securities owned by the household must satisfy the consumption Euler equation. If other agents (such as an intermediary) are willing to pay more for an asset than the household, the price will not reflect the household's preferences. This is because the household is constrained from shorting assets it considers overvalued. Second, the extra marginal utility  $v'(d)$ , reflecting the "safe asset premium" households are willing to pay for riskless securities, depresses the risk-free rate. The interest rate  $i_d = \frac{u'(c_1)}{(v'(d)+Eu'(c_2))} - 1$  for safe assets would equal the strictly higher rate  $\frac{u'(c_1)}{Eu'(c_2)} - 1$  if  $v'(d) = 0$ . Safe asset demand leads to a low risk-free rate relative to the pricing of other assets owned by the household, as (Krishnamurthy Vissing-Jorgensen 2012) shows empirically in the pricing of treasury securities. This is illustrated below.



If all asset prices reflected the household's willingness to pay, the gap between the risk-free rate and the pricing of risky assets could be exploited by an arbitrage trade. Suppose that a financial intermediary buys a diversified portfolio  $q_I(\cdot)$  of risky assets that pays  $\int \delta_s q_I(s) ds = \delta_p$  equal to  $\delta_{p,good}$  in the good state and  $\delta_{p,bad} < \delta_{p,good}$  in the bad state. The price of this portfolio is  $E \left[ \frac{u'(c_2)}{u'(c_1)} \delta_p \right]$ . If the intermediary sells a riskless security backed by its portfolio paying  $\delta_{p,bad}$  and a residual claim paying  $\delta_{p,good} - \delta_{p,bad}$  in the good state, the household would be willing to pay  $E \left[ \frac{u'(c_2)}{u'(c_1)} \delta_p \right] + \frac{v'(d)}{u'(c_1)} \delta_{p,bad}$  to buy both securities issued by the intermediary. This yields an arbitrage profit of  $\frac{v'(d)}{u'(c_1)} \delta_{p,bad}$ , equal to the quantity  $\delta_{p,bad}$  of riskless assets produced by the arbitrage trade times the "safety premium"  $\frac{v'(d)}{u'(c_1)}$  that households will pay for a riskless asset. This arbitrage trade, selling safe and risky tranches backed by a diversified portfolio of risky assets, is precisely what I refer to as safety transformation. The next section develops a model of how intermediaries exploit this arbitrage opportunity and the frictions they face when doing so.

**Intermediary's problem** The intermediary is a publicly traded firm that maximizes the value of its equity subject to an agency problem faced by its management. Unlike the household, the intermediary is able to issue securities backed by its asset portfolio, allowing it to increase the supply of riskless assets. It can raise funds either by issuing equity or other possible securities, and in equilibrium all securities it issues must be sold to the household. Riskless securities issued by the intermediary trade at the risk-free rate (reflecting the household's safety demand), while risky securities are priced by the consumption Euler equation. The cashflows  $(\delta_{I,1}, \delta_{I,2})$  paid by the intermediary at  $t = 1, 2$  in risky securities are valued as

$$E \left[ \frac{u'(c_2)}{u'(c_1)} \delta_{I,2} \right] + \delta_{I,1}. \quad (5)$$

Because this value does not depend on how the intermediary divides its risky cashflows (i.e. into a risky debt security as well as equity), the intermediary can be assumed to issue only equity and riskless debt without loss of generality.

The management of the intermediary faces an agency problem because the assets on its balance sheet have payoffs that are observable only to its management.<sup>12</sup> As a result, the intermediary's management is able to misreport the payoff of its asset portfolio and divert part of the difference between the true and reported payoff. If the true portfolio payoff is  $\delta_{P,true}$  and the intermediary reports  $\delta_{P,reported} < \delta_{P,true}$ , the management can divert  $C(\delta_{P,true} - \delta_{P,reported}) < \delta_{P,true} - \delta_{P,reported}$ . Management must therefore be given some profit sharing to incentivize for truthful reporting. Because the intermediary's portfolio is not exposed to idiosyncratic risk, its payoff at time 2 depends only on the binary aggregate state. Management's payment cannot explicitly depend on the uncontractible aggregate state or the output of other firms but only on the intermediary's cashflows that management reports. The intermediary's management therefore needs only a payment  $C(\delta_{P,good} - \delta_{P,bad})$  in the good state to ensure the truthful reporting of its asset payoff, where  $\delta_{P,s}$  is the payoff of its portfolio in state  $s$ . Because management diverts less than the total amount of output it destroys, it is optimal to induce management not to divert funds. Since this risky payoff cannot be used to back deposits and therefore must be sold as part of the intermediary's equity, the agency problem faced by the intermediary can be interpreted as a cost of raising equity capital. The cost  $C(\delta_{P,good} - \delta_{P,bad})$  can also be interpreted as a reduced form cost of paying dividends to the intermediary's equityholders, since  $\delta_{P,bad}$  is the amount of riskless deposits it can issue.

At time 1, the equity  $e_1$  raised by the intermediary is a negative payout  $\delta_{I,1} = -e_1$ . At time 2, the intermediary's payout is the total cashflows from its security portfolio minus the promised payments to depositors and management  $\delta_{I,2} = \int_0^1 \delta_s q_I(s) ds - d - C\left(\int_0^1 (\delta_s - E_{bad}\delta_s) q_I(s) ds\right)$ , where  $q_I(s)$  is the quantity of security  $s$  purchased by the intermediary. The intermediary's problem can be written as

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<sup>12</sup>As noted above, the intermediary (and non-financial firms) also faces a second agency problem between its owners and other investors, where owners can instruct management to divert resources or raise additional funding to manipulate security payoffs. Because this agency problem has no effect when a firm issues only debt and equity, the analysis in this section ignores it since these are the only securities the intermediary issues.

$$\begin{aligned}
& \max_{e_1, d, q_I(\cdot)} E \left[ \frac{u'(c_2)}{u'(c_1)} \left( \overbrace{\int_0^1 \delta_s q_I(s) ds}^{\text{cashflows}} - d - C \left( \overbrace{\int_0^1 (\delta_s - E_{bad} \delta_s) q_I(s) ds}^{\text{payments to depositors and management}} \right) \right) \right] - \underbrace{e_1}_{\text{equity issued}} \quad (6) \\
& \text{subject to: } e_1 + \frac{d}{1+i_d} = \int_0^1 p_s q_I(s) ds \quad (\text{budget constraint}) \\
& \left( \int_0^1 \delta_s q_I(s) ds - d \right) \geq 0 \text{ in all states of the world } (\text{solvency constraint}) \\
& q_I(\cdot) \geq 0 \quad (\text{short sale constraint}).
\end{aligned}$$

To simplify this problem, note that the budget constraint implies  $e_1 = \int_0^1 p_s q_I(s) ds - \frac{d}{1+i_d}$ . In addition, because of the safety premium, deposits are a cheaper source of funding for the intermediary than equity. The intermediary should therefore enough deposits to make its solvency constraint bind. This implies  $d = \int (E_{bad} \delta_s) q_I(s) ds$ , since  $E_{bad} \delta_s \leq E_{good} \delta_s$  so the solvency constraint binds in the bad state.

The intermediary's problem reduces to

$$\max_{q_I(\cdot) \geq 0} E \left[ \frac{u'(c_2)}{u'(c_1)} \left( \int_0^1 \delta_s q_I(s) ds - C \left( \int_0^1 (\delta_s - E_{bad} \delta_s) q_I(s) ds \right) \right) - \int_0^1 p_s q_I(s) ds + \frac{v'(d)}{u'(c_1)} \int_0^1 (E_{bad} \delta_s) q_I(s) ds \right] \quad (7)$$

which has the first order condition for each  $q_I(s)$

$$\begin{aligned}
p_s \geq & \underbrace{E \frac{u'(c_2)}{u'(c_1)} \delta_s}_{\text{household's willingness to pay}} + \underbrace{\frac{v' \left( \int (E_{bad} \delta_s) q_I(s) ds \right)}{u'(c_1)}}_{\text{safety premium}} \underbrace{E_{bad} \delta_s}_{\text{deposits backed by asset}} - \\
& \underbrace{C' \left( \int_0^1 (E_{good} \delta_s - E_{bad} \delta_s) q_I(s) ds \right)}_{\text{agency cost of equity}} \underbrace{\frac{1}{2} \frac{u'(c_2^{good})}{u'(c_1)}}_{\text{equity required to buy asset}} (E_{good} \delta_s - E_{bad} \delta_s)
\end{aligned} \quad (8)$$

with equality whenever  $q_I(s) > 0$ . This expression uses the fact that  $C'(\cdot) \neq 0$  only in the good state, since management must be paid only then.

The intermediary's willingness to pay for asset  $s$  depends only on  $E_{good}\delta_s$  and  $E_{bad}\delta_s$ , since the intermediary's portfolio is diversified. The distribution each asset's idiosyncratic returns given the aggregate state is irrelevant. By pooling and then tranching a portfolio of assets, the intermediary diversifies away its exposure to idiosyncratic risk. The intermediary can therefore back more riskless assets than would be possible by selling junior and senior tranches backed by individual assets. This is related to "risk diversification effect" of (DeMarzo 2005), who finds that pooling and tranching is an optimal strategy for issuing safe, informationally insensitive assets in the presence of asymmetric information.

The intermediary's required return for exposure to aggregate risk reflects its cost of equity financing and cheapness of deposit financing. As part of a diversified portfolio, a quantity  $E_{bad}\delta_s$  of riskless securities can be backed by asset  $s$ , while the remaining good state payoff  $E_{good}\delta_s - E_{bad}\delta_s$  increases the agency costs of equity. Because deposits earn the safety premium reflected in a low risk-free rate, the intermediary is willing to pay more than the household for assets that back large quantities of deposits. However, any systematic risk in an asset owned by the intermediary increases the intermediary's agency cost of equity financing. This makes the intermediary effectively more risk averse than the household.

**Asset prices and portfolio choices** The investment decisions of the household and intermediary described above can be used to solve for asset prices and determine which assets are owned by which investor. Assets owned by the intermediary imply a strictly lower risk-free rate and higher price of systematic risk than assets owned by the household. This segmentation in asset prices reflects the intermediary's ability to back riskless deposits with its asset portfolio and its agency cost of bearing risk. Low systematic risk assets are held by the intermediary and high systematic risk assets are held by the household, allowing the intermediary to issue many deposits while minimizing the agency costs it faces.

An expression for asset prices follows directly from the consumer's and intermediary's optimal investment decisions 4 and 8. Since every asset must be owned by some agent, at least one of these inequalities must hold with equality. If the household and intermediary are willing to pay different amounts for an asset, the agent willing to pay the most buys its entire supply. This yields the following result.

**Proposition 1** (*segmented asset prices*) *For any asset  $s$  in positive supply with payoffs  $\delta_s$  at time 2, its*

price at time 1 is the maximum of the willingness to pay of the two agents

$$\begin{aligned}
p_s = & \overbrace{E \left[ \frac{u'(c_2)}{u'(c_1)} \delta_s \right]}^{\text{household's willingness to pay for asset}} + \overbrace{\max[0, E_{bad} \delta_s]}^{\text{safe debt backed by asset}} \overbrace{\frac{v' \left( \int_0^1 (E_{bad} \delta_s) q_I(s) ds \right)}{u'(c_1)}}^{\text{safety premium}} \\
& - \frac{\overbrace{u' \left( c_2^{good} \right) [(E_{good} \delta_s - E_{bad} \delta_s)]}^{\text{equity required to purchase asset}}}{2u'(c_1)} \overbrace{C' \left( \int_0^1 (E_{good} \delta_s - E_{bad} \delta_s) q_I(s) ds \right)}^{\text{agency cost of equity}}. \tag{9}
\end{aligned}$$

If the household and intermediary are willing to pay different prices for asset  $s$ , the entire supply of the asset is bought by the agent willing to pay more.

The pricing kernel of assets owned by the intermediary implies a risk-free rate  $\left[ E \frac{u'(c_2) + v' \left( \int_0^1 (E_{bad} \delta_s) q_I(s) ds \right)}{u'(c_1)} \right]^{-1} - 1$ , strictly below the risk-free rate  $\left( E \frac{u'(c_2)}{u'(c_1)} \right)^{-1} - 1$  implied by the pricing kernel of risky assets owned by the household. This is because the intermediary can use riskless payoffs to back deposits and meet the household's safety demand, while the household is unable to pool and tranche to create riskless assets.

Assets owned by the intermediary reflect a strictly higher price of systematic risk than assets owned by the household. A unit of consumption in the good state is worth  $\frac{1}{2} \frac{u'(c_2^{good})}{u'(c_1)}$  to the household but only  $\frac{1}{2} \frac{u'(c_2^{good})}{u'(c_1)} \left( 1 - C' \left( \int_0^1 (E_{good} \delta_s - E_{bad} \delta_s) q_I(s) ds \right) \right)$  to the intermediary. The multiplicative factor  $1 - C'(\cdot)$  reflects the fact that good state payoffs increase the intermediary's agency costs, making these payoffs less valuable. This agency cost implies that the intermediary requires greater compensation for being exposed to systematic risk than the household.

This asset pricing result also characterizes the portfolios of the household and intermediary. The difference between these two agents' willingness to pay for asset  $s$  is

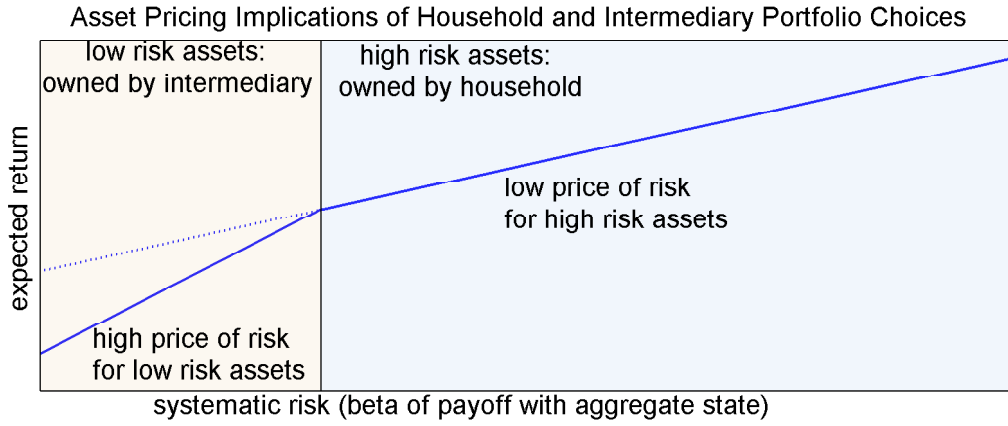
$$\begin{aligned}
& \frac{v' \left( \int_0^1 (E_{bad} \delta_s) q_I(s) ds \right)}{u'(c_1)} E_{bad} \delta_s - \\
& C' \left( \int_0^1 [(E_{good} - E_{bad}) \delta_s] q_I(s) ds \right) \frac{u' \left( c_2^{good} \right)}{2u'(c_1)} [(E_{good} - E_{bad}) \delta_s]. \tag{10}
\end{aligned}$$

The intermediary buys assets for which expression 10 is positive, while the household buys assets for which

it is negative. The sign of the expression is determined by the ratio  $\frac{E_{good}\delta_s}{E_{bad}\delta_s}$ , yielding the following corollary.

**Corollary 2** (*intermediary owns low systematic risk assets*)

Let  $k^* = 1 + \frac{2v'(\int(E_{bad}\delta_s)q_I(s)ds)}{u'(c_2^{good})C'(\int_0^1(E_{good}\delta_s - E_{bad}\delta_s)q_I(s)ds)}$ . The intermediary buys all assets who cashflows  $\delta_s$  satisfy  $\frac{E_{good}\delta_s}{E_{bad}\delta_s} < k^*$ , and the household buys all assets with  $\frac{E_{good}\delta_s}{E_{bad}\delta_s} > k^*$ . The pricing kernel for riskier assets owned by the household implies a strictly higher risk-free rate and strictly lower price of systematic risk than the pricing kernel for less risky assets owned by the intermediary.



These asset pricing and portfolio choice results can be summarized by the "kinked" securities market line above. Low risk assets owned by the intermediary earn a higher risk-adjusted return than high risk assets owned by the household. This segmentation occurs because intermediaries obtain cheap financing by meeting the household's demand for safe assets. In models with leverage constraints (e.g. Frazzini Pedersen 2014, Black 1972) agents who are more easily able to borrow can take risk by holding levered portfolios of low risk assets. Risk tolerant agents who are borrowing constrained must hold unlevered portfolios of high risk assets, bidding up the prices of these assets. The intermediary's ability to hold a diversified pool of assets that backs a large riskless tranche of debt is the advantage it has in borrowing.

**Non-financial firm's problem** This section shows how non-financial firms issue securities to exploit asset market segmentation. The intermediary is willing to pay more than the household for securities with low systematic risk but less for securities with high systematic risk. Non-financial firms therefore find it optimal to sell a low risk security to the intermediary and a high risk security to the household, obtaining a strictly higher valuation than either investor would pay for the entire firm. Under the restrictions imposed



below, the firm optimally chooses to issue debt bought by the intermediary and equity bought by the household. Its optimal leverage is determined by the risk preferences of the household and intermediary, illustrating how market segmentation violates the Modigliani-Miller theorem.

Each non-financial firm  $i \in [0, 1]$  has exogenous cashflows  $f_i$  at time 2, subject to aggregate and idiosyncratic shocks.  $f_i$  is respectively distributed according to  $F(f_i|good)$  and  $F(f_i|bad)$  in the good and bad aggregate states. The cashflows of non-financial firms are conditionally independent given the aggregate state. I impose the following condition on  $f_i$ . It implies that more senior claims on the firm's cashflows have lower systematic risk, so a more levered firm has debt with higher systematic risk.<sup>13</sup>

**Condition 3** (i)  $\frac{\partial}{\partial D} \frac{\Pr(f_i > D|good)}{\Pr(f_i > D|bad)} > 0$  for all  $D > 0$ .

(ii)  $\Pr(f_i > 0|good) = \Pr(f_i > 0|bad) = 1$

(iii)  $\lim_{D \rightarrow \infty} \frac{\Pr(f_i > D|good)}{\Pr(f_i > D|bad)} = \infty$

Non-financial firms are subject to the same agency problems as the intermediary between its owners and management and also between owners and other investors. If the true cashflow is  $f_i$  and the firm's management gives  $f'_i < f_i$  to outside investors, it can divert  $C(f_i - f'_i)$ . The firm faces a second agency problem between its owners and other outside investors, that after management has diverted funds, the owners can either destroy resources or covertly raise additional financing at the market rate (both raised and paid back in period 2). As in (Innes 1990), this agency problem between owners and other investors forces owners to issue securities whose payoffs are increasing in the firm's cashflows. The firm also cannot issue securities whose payoffs explicitly depend on the uncontractible aggregate good or bad state.

The appendix shows that the firm optimally issues debt and equity securities and provides its management with the incentive to never divert resources. The remainder of this section takes this result as given and analyzes the firm's optimal capital structure. In the previous section, it was shown without loss of generality that the intermediary would choose to issue equity and riskless debt, so the optimal behavior of the intermediary is not constrained by this additional agency problem.

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<sup>13</sup>Condition 3 (i) is equivalent to the monotone hazard ordering  $\frac{f_{f_i}(D|good)}{\Pr(f_i > D|good)} < \frac{f_{f_i}(D|bad)}{\Pr(f_i > D|bad)}$  where  $f_{f_i}(\cdot|H)$  is the conditional density of  $f_i$  given state  $H$ .

**Proposition 4** *Each non-financial firm  $i$  with cashflows  $f_i$  chooses to pay its management  $C(f_i)$ , which makes it incentive compatible for management to truthfully report the firm's earnings. The remaining cashflows  $x_i = f_i - C(f_i)$  are optimally divided into a debt security of face value  $D_i$  which pays  $x_i^D = \min(x_i, D_i)$  and an equity security which pays  $x_i^E = \max(x_i - D_i, 0)$ . Once  $f_i$  is reported to the firm's owners, it is optimal for the owners to neither raise additional hidden financing or to destroy resources.*

Firm  $i$ 's cashflows  $x_i = f_i - C(f_i)$  available to outside investors and its choice to issue debt and equity are now taken as given. Since  $f_i - C(f_i)$  is strictly increasing in  $f_i$ , the condition imposed on  $f_i$  also applies to  $x_i$ . The non-financial firm maximizes its total market value by choosing its face value of debt  $D_i$ . The firm takes as given asset prices implied by the behavior of the household and intermediary. Proposition 2 implies that the sum of the firm's debt and equity prices can be written as

$$p_E^i + p_D^i = E \frac{u'(c_2)}{u'(c_1)} x_i + \max(0, K_1 E_{bad} x_i^D - K_2 (E_{good} - E_{bad}) x_i^D) + \max(0, K_1 E_{bad} x_i^E - K_2 (E_{good} - E_{bad}) x_i^E) \quad (11)$$

where  $K_1 = \frac{v'(\int_0^1 (E_{bad} \delta_s) q_I(s) ds)}{u'(c_1)} > 0$  and  $K_2 = \frac{u'(c_2^{good})}{2u'(c_1)} C' \left( \int_0^1 (E_{good} \delta_s - E_{bad} \delta_s) q_I(s) ds \right) > 0$ . The signs of these two constants reflect the fact that the intermediary is willing to pay more than the household for riskless payoffs but less for payoffs in the good state. If  $K_1 = K_2 = 0$ , which would hold if household and intermediary were willing to pay the same for all securities, firm  $i$ 's market value would be independent of its capital structure. The fact that  $p_E^i + p_D^i$  depends on the face value of debt  $D_i$  illustrates how asset market segmentation violates Modigliani-Miller. This is related to (Baker Hoeyer Wurgler 2016), who argues empirically that market segmentation influences capital structure decisions.<sup>14</sup>

The firm chooses the face value of debt  $D_i$  to maximize its market value  $p_D^i + p_E^i$ . If there is a  $D_i$  at which the intermediary buys one security issued by the firm and the household buys the other,  $p_E^i + p_D^i$  must be strictly greater than either investor's willingness to pay for the firm's total cashflows  $x_i$ . If such a

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<sup>14</sup>The analysis in this section provides a somewhat novel framework for analyzing corporate capital structure. The idea that risk aversion heterogeneity can influence corporate capital structure is presented in (Allen Gale 1988) but only in the case where debt is riskless, and the idea does not seem to appear in later literature. The analysis here is mathematically similar to (Simsek 2013)'s study of collateralized margin lending under belief disagreement.

$D_i$  is optimal, it must satisfy the first order condition

$$K_1 \Pr(x_i > D_i | bad) - K_2 (\Pr(x_i > D_i | good) - \Pr(x_i > D_i | bad)) = 0 \quad (12)$$

since  $\frac{\partial E_H x_i^D}{\partial D_i} = \frac{\partial E_H \min(x_i, D_i)}{\partial D_i} = \Pr(x_i > D_i | H) = -\frac{\partial E_H x_i^E}{\partial D_i}$  for  $H = bad$  and  $H = good$ . This condition implies that a security which pays 1 when  $x_i > D_i$  and 0 otherwise is of equal value to the household and the intermediary. Because an increase in  $D_i$  increases the payout of debt only in states of the world where  $x_i > D_i$ , this marginal transfer of resources from equity to debt has no effect on firm  $i$ 's total market value  $p_E^i + p_D^i$ .

The first order condition 12 uniquely determines the ratio  $\frac{\Pr(x_i > D_i | good)}{\Pr(x_i > D_i | bad)}$ . For this ratio to determine firm  $i$ 's capital structure, there must be precisely one  $D_i$  for which 12 holds, which follows from the assumption that  $\frac{\Pr(x_i > D_i | good)}{\Pr(x_i > D_i | bad)}$  is strictly increasing in  $D_i$  and has range  $[1, \infty)$ .

As well as providing a unique solution to equation 12 for any  $K_1, K_2 > 0$ , this condition also implies that

$$\frac{E_{good}(\min(x_i, D_i))}{E_{bad}(\min(x_i, D_i))} < \frac{\Pr(x_i > D_i | good)}{\Pr(x_i > D_i | bad)} < \frac{E_{good}(\max(x_i - D_i, 0))}{E_{bad}(\max(x_i - D_i, 0))}. \quad (13)$$

When  $D_i$  satisfies 12, firm  $i$ 's debt has low enough systematic risk to be bought by the intermediary, while firm  $i$ 's equity is bought by the household. This verifies that 12 determines firm  $i$ 's unique optimal capital structure. Plugging in the definitions of  $K_1$  and  $K_2$  yields the following proposition.

**Proposition 5** (*optimal non-financial capital structure*) *If condition 3 is satisfied, the optimal face value of debt  $D_i$  for firm  $i$  is the unique  $D_i$  which solves*

$$v' \left( \int_0^1 [E_{bad} \delta_s] q_I(s) ds \right) - \frac{1}{2} u' \left( c_2^{good} \right) C' \left( \int_0^1 [(E_{good} - E_{bad}) \delta_s] q_I(s) ds \right) \left( \frac{\Pr(x_i > D_i | good)}{\Pr(x_i > D_i | bad)} - 1 \right) = 0. \quad (14)$$

*When  $D_i$  is chosen optimally, firm  $i$ 's debt and equity are respectively bought by the intermediary and the household.*

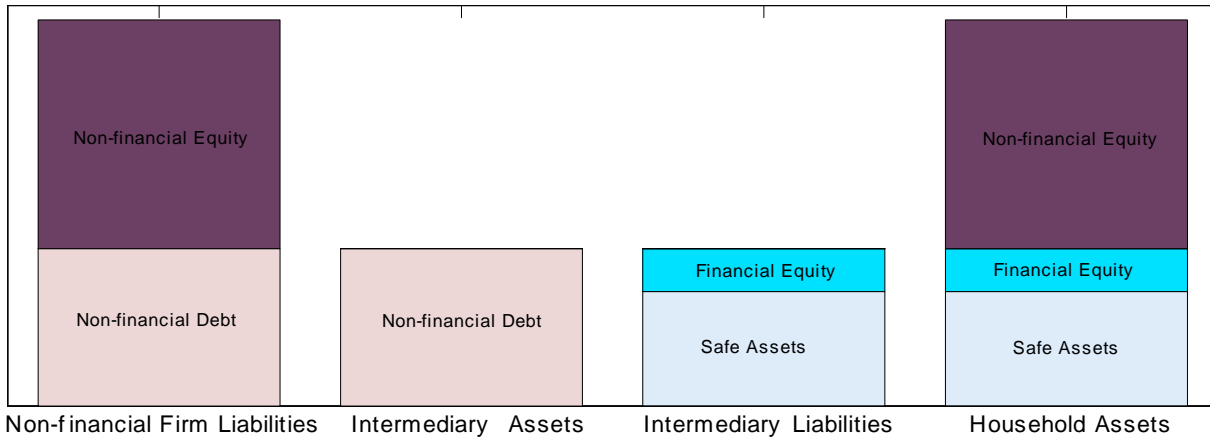
The intermediary's ability to issue cheap riskless debt implies that non-financial firms are also able to issue cheap debt as long as its systematic risk is low enough. As shown above, the intermediary's

cost of capital is reflected in segmented asset prices. This proposition builds on this result by showing how the non-financial sector responds to market segmentation. The household's demand for safe assets (measured by  $v' \left( \int_0^1 [E_{bad} \delta_s] q_I(s) ds \right)$ ) and the intermediary's agency cost of equity (measured by  $C' \left( \int_0^1 [(E_{good} - E_{bad}) \delta_s] q_I(s) ds \right)$ ) jointly determine the non-financial sector's optimal capital structure.

The proposition provides a cross-sectional prediction for capital structure. Firms for whom  $\frac{\Pr(x_i > D_i | good)}{\Pr(x_i > D_i | bad)}$  is greater at each  $D_i$  choose to issue less debt. This is consistent with (Schwert and Strebulaev 2015)'s finding that firms with more cyclical cashflows are less levered.

The results derived above can be thought of as applying to household borrowing. If the household could buy a durable consumption good providing consumption services  $x_i$  and get a collateralized loan of face value  $D_i$  backed only by this consumption good (such as a mortgage backed by a house), the optimal amount to borrow would also be described by condition 14.

Composition of Balance Sheets in Equilibrium



This proposition also determines the composition of household, intermediary, and non-financial firm balance sheets. Households invest in the equity of both the financial and non-financial sectors and also hold safe assets. Intermediaries, who supply the safe assets, invest in the debt of the non-financial sector and must issue a buffer of equity to bear the risk in their portfolio of debt securities. Non-financial firms sell their debt to intermediaries and equity to households, arbitraging the differing prices of risk for low and high risk securities. The fact that equities are held by households while debt securities are held by the intermediary is endogenous and not assumed. Any agent is able to buy any security, but intermediaries

are willing to pay more for debt securities but less for equities than households.<sup>15</sup>

One final implication of this proposition is that it explains the "credit spread puzzle" in debt securities and "low risk anomaly" in equities. The capital structure choices of the non-financial sector ensure debt and equity securities live on opposite sides of the kink in the securities market line. As a result, the debt and equity markets are endogenously segmented, with a greater price of risk in the debt market. As shown in (Huang and Huang 2012), many structural credit risk models underestimate the spreads on corporate bonds when calibrated to data from equity markets, a finding referred to as the credit spread puzzle. Such a result can either be interpreted as a failure of many structural models (and some recent ones do match it in a no arbitrage framework) or taken as evidence that risk is priced more expensively in debt markets than in equity markets, as naturally occurs in my model. The high price of risk in debt markets occurs jointly with a low price of risk in equity markets. This rationalizes the "low risk anomaly" (e.g. Black, Jensen, Scholes 1972, Baker, Bradley, Taliaferro 2014), which finds that for simple measures of risk (such as covariance with returns on an equity market index), the price of systematic risk in equity markets is too small to jointly explain a low risk-free rate and high expected return on equities. This naturally occurs in my model, since the zero beta rate implied by the pricing of equities is strictly above the true risk-free rate, with the spread reflecting the demand for safe assets.

**Equilibrium** This section characterizes the model's equilibrium, endogenously determining the intermediary's cost of capital, which has been taken as given in the results above.

**Definition 6** *An equilibrium is a set of consumption allocations  $(c_1, c_2)$ , intermediary and household portfolios  $(q_I(s), q_H(s))_{s \in [0,1]}$ , asset prices  $(p_s)_{s \in [0,1]}$ , deposits  $d$ , intermediary equity and non-financial firm debt issuance  $(D_i)_{i \in [0,1]}$  such that*

- (i) *The household, intermediary, and non-financial firms behave optimally as described above.*
- (ii) *Household and intermediary budget constraints are satisfied.*
- (iii) *Consumption at time 2 equals the total output of the non-financial sector,  $c_2 = \int_0^1 f_i di$ , and consumption at time 1 equals output at time 1,  $c_1 = C_1$ .*

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<sup>15</sup>If the non-financial firms were able to issue some riskless debt (ruled out by  $\frac{\partial}{\partial D_i} \frac{\Pr(f_i > D_i | good)}{\Pr(f_i > D_i | bad)} > 0$ ), an equilibrium in which households held both financial debt and a riskless senior tranche of non-financial debt could also occur.

Because the intermediary's portfolio is composed entirely of the debt of the non-financial sector as shown in proposition 4, the quantity  $d$  of riskless assets the intermediary can issue and residual payoff  $e$  to equityholders in good states are simply

$$d = \int_0^1 E_{bad} \min(x_i, D_i) di. \quad (15)$$

$$e = \int_0^1 (E_{good} - E_{bad}) \min(x_i, D_i) di. \quad (16)$$

Plugging these expressions into each firm  $i$ 's optimal capital structure decision yields

$$v' \left( \int_0^1 E_{bad} \min(x_i, D_i) di \right) - \frac{u'(c_2^{good})}{2} C' \left( \int_0^1 (E_{good} - E_{bad}) \min(x_i, D_i) di \right) \left( \frac{\Pr(x_i > D_i | good)}{\Pr(x_i > D_i | bad)} - 1 \right) = 0. \quad (17)$$

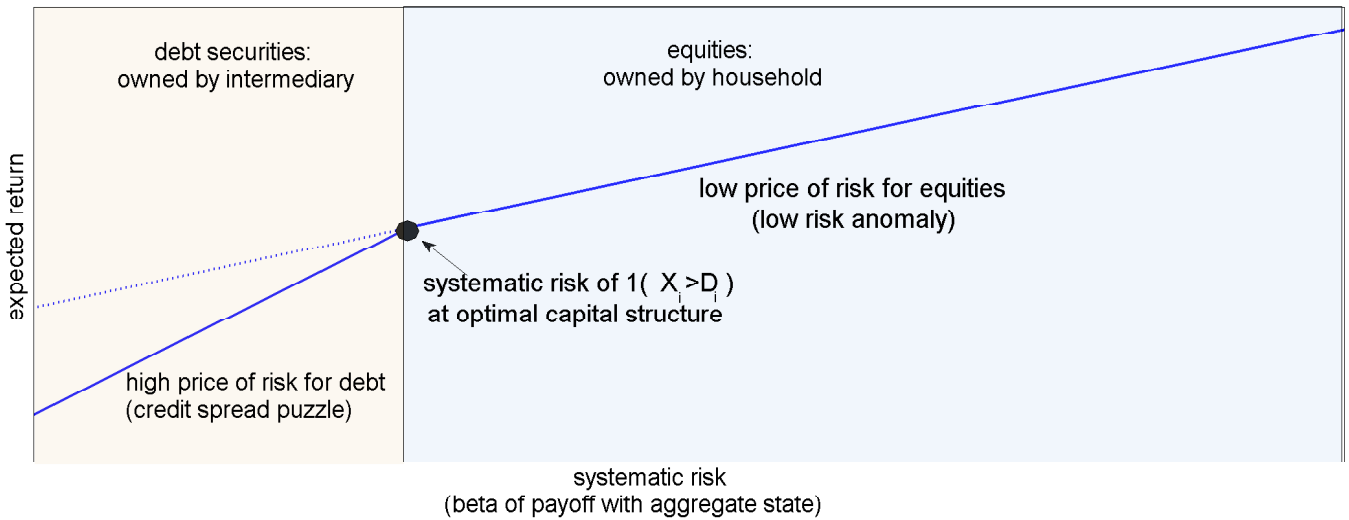
which depends only on exogenous variables and the face value of debt  $D_i$  each non-financial firm issues.

**Proposition 7 (equilibrium)** *The model's unique equilibrium is characterized by a face value of debt  $D_i$  for each non-financial firm  $i$  that solves equation 17*

**Proof.** Under the regularity conditions on each firm  $i$ 's cashflows, the ratio  $r = \frac{\Pr(x_i > D_i | good)}{\Pr(x_i > D_i | bad)}$  uniquely determines the debt face value  $D_i$  of each firm  $i$ , and  $D_i$  is continuous and increasing in  $r$ . The expression in equation 17 is a strictly decreasing function of  $r$ ,  $M(r)$ , which equals 0 in equilibrium.  $M(0) > 0$  and  $M(\infty) < 0$ , so  $M$  crosses zero once and a unique equilibrium exists. ■

This characterization of equilibrium illustrates the interaction between three forces. The household's demand for safe assets reflected in the function  $v(\cdot)$  determines how great the incentives are for the intermediary to create riskless assets. The cost of creating riskless assets depends on the severity of the intermediary's agency problem which is reflected in the function  $C(\cdot)$ , which determines how costly it is for the intermediary to own risky assets. Finally, the cost of creating riskless assets depends on how much risk the intermediary must take in order to back a given quantity of riskless assets. This is determined by the distribution of each firm's marketable cashflows  $x_i$ . The more systematic risk non-financial firms are exposed to, the more costly equity financing is required for the intermediary to back deposits.

Equation 17 illustrates how the intermediary's portfolio which pays  $\int_0^1 \min(x_i, D_i) di$  determines the intermediary's cost of capital, both in terms of the premium  $v' \left( \int_0^1 E_{bad} \min(x_i, D_i) di \right)$  on riskless deposits and the cost  $C' \left( \int_0^1 (E_{good} - E_{bad}) \min(x_i, D_i) di \right)$  of a marginal increase in the riskiness of the intermediary's portfolio. These costs, which are reflected in equilibrium asset prices then determine the optimal capital structure of the non-financial sector. Because the debt of the non-financial sector is the asset side of the intermediary's balance sheet, ensuring that the non-financial sector issues the optimal amount of debt at the intermediary's equilibrium cost of capital solves for the model's unique equilibrium.



The above diagram summarizes the implications of this equilibrium. The low risk assets owned by the intermediary are now the debt of the non-financial sector, while the high risk assets owned by the household are now the equity of both the financial and non-financial sectors. As a result, the market price of risk is strictly higher in the debt than the equity market as discussed above. The optimal capital structure of the non-financial sector is determined by how segmented the debt and equity markets are. The optimal non-financial capital structure arbitrages between these two markets, with the first order condition that a small increase in leverage has no marginal effect on a non-financial firm's value. This first order condition is summarized by the dot in the above diagram, since the payoff  $1(x_i > D_i)$  is the marginal transfer from equity to debt of increasing firm  $i$ 's leverage. The household and intermediary have the same willingness to pay for  $1(x_i > D_i)$ , which implies that it must lie at the intersection of their two security market lines. In equilibrium, the gap between the two intercepts is determined by the premium on riskless assets, while the higher slope of the intermediary's security market line reflects its agency costs of owning risky assets.

**Discussion** Three basic assumptions are crucial for the model's key results. First, there must be a demand for safe, money-like assets that pushes the risk-free rate below the rate implied by the pricing of equities. This gives intermediaries and non-financial firms an incentive to separate their assets into safe and risky tranches in order to borrow as much as possible at the low risk-free rate. Second, the non-financial sector must face some constraints that make it difficult for them to issue safe assets directly. Because non-financial firms are exposed to (full support) idiosyncratic risk they cannot hedge and issue debt and equity rather than arbitrary Arrow-Debreu securities, they cannot issue riskless assets. Finally, intermediaries must face some cost of bearing risk, so that they choose to only buy low risk debt securities. If intermediaries had no cost of bearing risk, they would buy the entire non-financial sector in order to use its entire output in the bad state of the world to back the safe debt they issue. Equation 17 illustrates in a single expression how these three basic assumptions interact. The benefit  $v'(\cdot)$  of issuing more riskless securities are balanced against the agency cost  $C'(\cdot)$  of increasing the risk on the intermediary's balance sheet, where the amount of risk bearing required is determined by the ratio  $\frac{\Pr(x_i > D_i | good)}{\Pr(x_i > D_i | bad)}$  that depends on the riskiness of each non-financial firm's output.<sup>16</sup>

The assumption that households place a special value on riskless assets is common in both recent theoretical and quantitative models, is consistent with empirical evidence referenced in the introduction, but does not have a microfoundation in this paper or the related literature. In my model, only riskless assets are special, whereas one may imagine that bank deposits and money market fund shares are exposed to small risks while still being "money-like." (Gorton & Pennacchi 1990) provides a model that shows why riskless assets are the most liquid, but the question of how risky an asset can be while still functioning as a form of money is open. Assuming that deposits must be riskless ignores the possibility of bank runs which could be studied in a similar framework in which depositors withdraw only when deposits become too risky. However, if banks can tap a cheap source of funding by issuing low risk deposits, the basic insight of this paper still holds. Banks and similar intermediaries will choose the assets they hold to issue as many deposits and as little equity as possible if deposits are cheap and equity is expensive.

In order for my model of intermediation to be consistent with the data, the pricing kernels for low and

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<sup>16</sup>The agency problem that makes risk bearing costly for the intermediary also applies to non-financial firms so that all firms are ex ante identical. For non-financial firms whose project risk is exogenous, this agency problem is just an unavoidable cost that has no important implications.



high risk assets must be different. If there are no unexploited arbitrage opportunities, an intermediary cannot create value by buying publicly available securities in order to sell other publicly available securities. The paper's asset pricing implications therefore provide a falsifiable way of evaluating the model, which sets it apart from other models of financial intermediation that do not speak to the market for publicly available securities. While my model only provides qualitative predictions, it is consistent with both cross sectional and time series evidence on the credit spread puzzle and low risk anomaly. My model implies that the expected return on the riskiest bonds are close to the securities market line implied by equities, and (Huang and Huang 2012) show that the credit spread puzzle is much less severe for junk than investment grade bonds. In addition, (Gilchrist Zakrajsek 2012) show that in the time series, the severity of the credit spread puzzle comoves strongly with measures of intermediary risk taking. (Frazzini Pedersen 2014) also shows that the low risk (low beta) anomaly is largest when measures of distress in the intermediary sector are high. There is a literature that attempts to rationalize the asset pricing facts I emphasize in a no arbitrage framework, and it is an open question going forward whether a quantitative model with constrained intermediaries best explains the data.

To interpret the model, it is useful to ask what are the financial intermediaries it describes. Intermediaries in my model hold diversified portfolios of debt, issue a safe, senior liability (deposits) backed by this portfolio and a junior liability (equity) that bears the risk in the intermediary's asset portfolio. Banks are the most straightforward fit to the model, though certain elements of the shadow banking system such as broker dealer or investment banks fit as well. Broker dealer and investment banks often fund themselves heavily with short term debt (some of which is collateralized), and this short term debt is often bought by money market funds. Integrating the broker dealer and the money market fund creates an entity like the intermediary in my model, though broker dealers also provide unrelated services such as market making. Life insurers also similar to my model, though their liabilities are longer duration than banks and not money-like, so the demand for their liabilities is conceptually distinct. Key features missing from my model are capital requirements and deposit insurance, which may be important for ensuring that even agents who do not understand an intermediary's assets can assume their liabilities are safe.<sup>17</sup>

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<sup>17</sup>Deposit insurance can be thought of as a promise by the government to pay off depositors in states of the world where the intermediary is unable to pay. In my model, this is equivalent to providing the intermediary with payoffs in the bad state of the world that allow them to increase the supply of safe assets.

## 2 Applications

**Changes in the Supply and Demand for Safe Assets** The model developed in the previous section can be used to understand the general equilibrium effects of changes in the supply and demand for safe assets. Because the model endogenously determines asset prices, intermediary portfolios and leverage, and the capital structure of the non-financial sector, all of these will adjust in order to clear the market for safe assets. This provides a framework for understanding how the financial system responds to a safe asset shortage, which a macroeconomic literature (e.g. Caballero Farhi 2017) argues has been a key driving force behind the low real interest rates in recent decades. My model implies that a growing demand for safe assets causes something akin to the subprime boom of the 2000s. In particular, the financial sector expands and invests in riskier assets than it previously did, which leads to an increase in the leverage of the non-financial sector due to a reduction in its cost of borrowing.

To increase the demand for safe assets, I take the comparative static of increasing  $v'(d)$  for all  $d$  by one unit.<sup>18</sup> The effect of this is characterized by implicitly differentiating the equilibrium condition 17. For any  $x$ , let  $\frac{\partial x}{\partial v}$  be the derivative of  $x$  with respect to increasing  $v'$  by one unit. The ratio  $r = \frac{\Pr(x_i > D_i | good)}{\Pr(x_i > D_i | bad)}$  that characterizes the intermediary's portfolio satisfies

$$\underbrace{v''(d) \frac{\partial d}{\partial r} \frac{\partial r}{\partial v}}_{\text{change in } v'(d) \text{ from expanding portfolio}} - \underbrace{\frac{u'(c_2^{good})}{2} C''(e) (r-1) \frac{\partial e}{\partial r} \frac{\partial r}{\partial v}}_{\text{change in } C'(e) \text{ from expanding portfolio}} - \underbrace{\frac{u'(c_2^{good})}{2} C'(e) \frac{\partial r}{\partial v}}_{\text{direct effect of change in } r} + 1 = 0 \quad (18)$$

where

$$\frac{\partial d}{\partial r} = \int_0^1 \Pr(x_i > D_i | bad) \frac{\partial D_i}{\partial r} di \quad (19)$$

$$\frac{\partial e}{\partial r} = \int_0^1 ([\Pr(x_i > D_i | good) - \Pr(x_i > D_i | bad)]) \frac{\partial D_i}{\partial r} di \quad (20)$$

$$\frac{\partial D_i}{\partial r} = \frac{\Pr(x_i > D_i | bad)^2}{\Pr(x_i > D_i | bad) f_{i,good}(D_i) - \Pr(x_i > D_i | good) f_{i,bad}(D_i)}. \quad (21)$$

<sup>18</sup>Formally, if  $v_\lambda(d) = v(d) + \lambda d$  is a family of functions indexed by  $\lambda$ , I am taking the (Gateaux) derivative with respect to  $\lambda$   $\frac{d}{d\lambda} v_\lambda(d) = \lim_{\lambda' \rightarrow \lambda} \frac{(v(d) + \lambda' d) - (v(d) + \lambda d)}{\lambda' - \lambda}$ .

The expression for  $\frac{\partial D_i}{\partial r}$  comes from implicitly differentiating  $\frac{\Pr(x_i > D_i | \text{good})}{\Pr(x_i > D_i | \text{bad})} = r$ , and  $\frac{\partial D_i}{\partial r} > 0$  is implied by the assumption  $\frac{\partial}{\partial D_i} \frac{\Pr(x_i > D_i | \text{good})}{\Pr(x_i > D_i | \text{bad})} > 0$ .  $\frac{\partial d}{\partial r}$  and  $\frac{\partial e}{\partial r}$  are therefore strictly positive. The change in the ratio  $r = \frac{\Pr(x_i > D_i | \text{good})}{\Pr(x_i > D_i | \text{bad})}$  that parametrizes each firm's optimal leverage changes as

$$\frac{\partial r}{\partial v} = \frac{1}{\frac{u'(c_2^{\text{good}})}{2} (C'''(e)(r-1)\frac{\partial e}{\partial r} + C'(e)) - v''(d)\frac{\partial d}{\partial r}} > 0. \quad (22)$$

The quantity of debt issued by firm  $i$ , deposits  $d$  issued by the intermediary, and good state equity payout  $e$  from the intermediary change as

$$\frac{\partial D_i}{\partial v} = \frac{\partial D_i}{\partial r} \frac{\partial r}{\partial v} > 0, \quad \frac{\partial d}{\partial v} = \frac{\partial d}{\partial r} \frac{\partial r}{\partial v} > 0, \quad \frac{\partial e}{\partial v} = \frac{\partial e}{\partial r} \frac{\partial r}{\partial v} > 0. \quad (23)$$

The change in the safety premium  $v'(d)$  equals  $1 - v''(d)\frac{\partial d}{\partial r}\frac{\partial r}{\partial v}$  which satisfies

$$1 > 1 - v''(d)\frac{\partial d}{\partial r}\frac{\partial r}{\partial v} = \left( C'''(e)(r-1)\frac{\partial e}{\partial r} + C'(e) \right) \frac{\partial r}{\partial v} > 0 \quad (24)$$

while the intermediary's willingness to pay for good state payoffs changes as

$$-\frac{1}{2} \frac{u'(c_2^{\text{good}})}{u'(c_1)} C'''(e) \frac{\partial e}{\partial v} < 0 \quad (25)$$

The increased safety premium and decreased value of good state payoffs to the intermediary implies that it is willing to pay more for sufficiently low (systematic) risk securities but less for sufficiently high risk securities. While some securities are so risky that the intermediary's willingness to pay for them decreases, the borrowing costs of all non-financial firms decrease. This can be seen from the fact that  $\frac{\partial r}{\partial v} > 0$ , implying that the intermediary is now willing to pay the same as the household for an asset of greater systematic risk  $r$ . Because  $\frac{E_{\text{good}} \min(x_i, D_i)}{E_{\text{bad}} \min(x_i, D_i)} < r$  for all firms  $i$ , the intermediary is also willing to pay strictly more for each firm's debt, reducing each firm's cost of borrowing. This completes the proof of the following result. As noted on the section on non-financial firms, non-financial firm debt can be relabeled to represent mortgage debt, so this result also implies household mortgage borrowing would increase.

**Proposition 8** (*safe asset demand*) *An increase in the demand for riskless securities, modeled as an*

increase in the function  $v'(d)$  causes:

1. An increase in the quantity  $d$  of riskless securities and intermediary equity issuance  $e$ .
2. A reduction in the risk-free interest rate and increase in credit spreads, with an overall reduction in borrowing costs for all firms.
3. An increase in the leverage of the non-financial sector

The second comparative static, creating a supply  $\mu$  of riskless securities backed by lump sum taxes on the household, simply increases the supply of safe assets from the liability  $d$  issued by the intermediary to the sum  $d + \mu$ . This crowds out the intermediary's incentive to perform safety transformation by providing a supply of safe assets that do not lie on the intermediary's balance sheet. For any given quantity  $d$  of deposits, the safety premium  $v'(d + \mu)$  is decreasing in  $\mu$ . The effect of this decrease is therefore precisely the opposite of the increase in  $v'(d)$  considered in the first comparative static. While the model in the previous section does not explicitly have government debt, riskless government debt can be mapped into the framework above by simply replacing  $v'(d)$  with  $v'(d + \mu)$ . The calculations for the effect of an increase in the demand for safe assets therefore also imply the following. Closed form derivatives for how variables adjust are simply  $-v''(d)$  times the results derived above for the increase in safe asset demand.

**Proposition 9** (*government debt supply*) *An increase in the supply  $\mu$  of riskless securities issued by the government causes*

1. An increase in the quantity  $d + \mu$  of total riskless securities, a decrease in riskless securities  $d$  issued by the intermediary, and decrease in intermediary equity issuance  $e$ .
2. An increase in the risk-free interest rate and compression of credit spreads, with an overall increase in borrowing costs for all firms.
3. A decrease in non-financial leverage.

**Quantitative Easing** A third possible policy experiment is to consider the effects of quantitative easing policies, in which the government issues safe debt in order to purchase risky securities. If the government buys equities, which are held by households, the effect on asset prices, leverage, and intermediary portfolios is identical to simply increasing the supply of government debt backed by more taxes. However,

the effects are more subtle when the government buys debt securities which are owned by intermediaries. Such a transaction replaces risky assets owned by the intermediary with riskless government debt and therefore can be seen as a combination of adding riskless assets to the intermediary's portfolio and removing good state payoffs. This has the effect of both increasing the supply of safe assets and decreasing the amount of risk the intermediary needs to bear.

To derive the effects of such asset purchases, I first compute the effect of removing good state payoffs from the intermediaries balance sheet. For any variable  $m$  I denote  $\frac{\partial m}{\partial good}$  the change in  $m$  that occurs when good state payoffs are removed from the intermediary's portfolio.

$$\left[ v''(d) \frac{\partial d}{\partial r} - \frac{u'(c_2^{good})}{2} \left[ C''(e) \frac{\partial e}{\partial r} (r-1) + C'(e) \right] \right] \frac{\partial r}{\partial good} = - \frac{u'(c_2^{good})}{2} C''(e) (r-1) \quad (26)$$

$$\frac{\partial r}{\partial good} = - \frac{\frac{u'(c_2^{good})}{2} C''(e) (r-1)}{v''(d) \frac{\partial d}{\partial r} - \frac{u'(c_2^{good})}{2} [C''(e) \frac{\partial e}{\partial r} (r-1) + C'(e)]} > 0 \quad (27)$$

$$\frac{\partial d}{\partial good} = \frac{\partial d}{\partial r} \frac{\partial r}{\partial good} > 0, \quad \frac{\partial e}{\partial good} = \frac{\partial e}{\partial r} \frac{\partial r}{\partial good} > 0 \quad (28)$$

The change in the safety premium  $v'(d)$  is

$$v''(d) \frac{\partial d}{\partial r} \frac{\partial r}{\partial good} < 0 \quad (29)$$

The change in the cost of equity  $\frac{u'(c_2^{good})}{2} C'(e)$  is equal to

$$\left[ v''(d) \frac{\partial d}{\partial r} - \frac{u'(c_2^{good})}{2} \left[ C''(e) \frac{\partial e}{\partial r} (r-1) + C'(e) \right] \right] \frac{\partial r}{\partial good} < 0. \quad (30)$$

As noted above, a purchase of risky assets owned by the intermediary financed by the issuance of riskless government debt increases the supply of riskless assets and removes good state payoffs from the intermediary's balance sheet. To compute the effects of asset purchases, I must figure out what weights

to place on the effects of adding riskless assets and removing good state payoffs from the intermediary's balance sheet. An asset purchase occurs at market prices, so the assets bought and sold must have the same price. If the government issues  $d$  units of debt to buy an asset that has an (expected) payoff of  $\delta_{good}$  in the good state and  $\delta_{bad}$  in the bad state, this can be seen as increasing the supply of riskless assets held by the intermediary by  $\mu = d - \delta_{bad}$  units while reducing the amount of good state payoffs on its balance sheet by  $r_{good} = \delta_{good} - d$ . A transaction at market prices must satisfy

$$[Eu'(c_2) + v'(d)] \mu = \frac{1}{2} u' \left( c_2^{good} \right) (1 - C'(e)) (-r_{good}) \quad (31)$$

An asset purchase removes  $\frac{[Eu'(c_2) + v'(d)]}{\frac{1}{2} u' \left( c_2^{good} \right) (1 - C'(e))}$  units of good state payoff from the intermediary's portfolio per unit of riskless payoff added, regardless of which asset is purchased. This adds  $\mu$  units of bad state payoff to the intermediary's portfolio while removing  $r_{good} - \mu$  good state payoffs.  $\mu$  is a sufficient statistic for the effect of the asset purchase. For any variable  $v$ , let  $\frac{\partial v}{\partial QE}$  be the change in  $v$  from purchases that increase the bad state payoff of the intermediary's portfolio by 1 unit, so  $\frac{\partial v}{\partial QE} = \frac{\partial v}{\partial \mu} - \frac{[Eu'(c_2) + v'(d)]}{\frac{1}{2} u' \left( c_2^{good} \right) (1 - C'(e))} \frac{\partial v}{\partial good}$ . These comparative statics have the same signs for the following variables, proving the following result.

**Proposition 10** (*asset purchases 1*) *Purchasing risky assets owned by the intermediary financed by the issuance of riskless government debt causes*

1. *An increase in the quantity  $d + \mu$  of total riskless securities, a decrease in riskless securities  $d$  issued by the intermediary, and decrease in intermediary equity  $e$ .*
2. *An increase in the risk-free interest rate and compression of credit spreads.*

The effect on corporate leverage, however, is ambiguous.

$$\left[ v''(d) \frac{\partial d}{\partial r} - \frac{u' \left( c_2^{good} \right)}{2} \left[ C''(e) \frac{\partial e}{\partial r} (r - 1) + C'(e) \right] \right] \frac{\partial r}{\partial QE} = \quad (32)$$

$$-v''(d) - \frac{[Eu'(c_2) + v'(d)]}{\frac{1}{2} u' \left( c_2^{good} \right) (1 - C'(e))} \left[ \frac{u' \left( c_2^{good} \right)}{2} C''(e) (r - 1) \right]$$

and has the opposite sign as the right hand side of equation 32. If  $\frac{\partial r}{\partial QE} < 0$ , then arguments made above imply that all firms have an increase in their borrowing costs. However, if  $\frac{\partial r}{\partial QE} > 0$ , then firms for whom  $\frac{E_{good} \min(x_i, D_i)}{E_{bad} \min(x_i, D_i)}$  is sufficiently close to  $r$  will have a decrease in borrowing costs, while firms for which this ratio is small enough face an increase in borrowing costs.

**Proposition 11** (*asset purchases 2*) *If*

$$-v''(d) - \frac{[Eu'(c_2) + v'(d)]}{\frac{1}{2}u'(c_2^{good})(1 - C'(e))} \left[ \frac{u'(c_2^{good})}{2} C''(e)(r - 1) \right] > 0 \quad (33)$$

*Purchasing assets owned by the intermediary financed by issuing riskless debt causes a decrease in corporate leverage and an increase in borrowing costs for all firms.*

*If this expression is negative, asset purchases cause an increase in leverage for all firms, an increase in borrowing costs for firms with  $\frac{E_{good} \min(x_i, D_i)}{E_{bad} \min(x_i, D_i)}$  sufficiently small, and a decrease in borrowing costs for firms with  $\frac{E_{good} \min(x_i, D_i)}{E_{bad} \min(x_i, D_i)}$  sufficiently large.*

**Nominal Rigidities and The Zero Lower Bound** This section adds a binding zero lower bound on monetary policy to the model developed above into a simple framework with nominal rigidities, which is the context under which the Federal Reserve's quantitative easing policies were performed. To maintain tractability, I make the extreme assumption that goods prices are perfectly rigid, following the original liquidity trap analysis of (Krugman 1998). Given this price rigidity, I assume that the central bank sets the interest rate  $i_d$  subject to the zero lower bound constraint  $i_d \geq 0$  which is motivated by the possibility that households will swap riskless bonds for cash when interest rates are negative.

Under flexible prices, the household's optimality condition for investing in riskless securities

$$u'(c_1) = (1 + i_d) [E(u'(c_2) + v'(d))] \quad (34)$$

determines the risk-free rate taking as given consumption  $(c_1, c_2)$  and the supply of riskless assets  $d$ . With sticky prices in the goods market at time 1, the variables at time 2  $(c_2, d)$  and the risk-free rate  $i_d$

set by the central bank determine the amount of consumption  $c_1$  that occurs at time 1, so long as  $c_1$  is not greater than the supply  $C_1$  of resources available to consume. When  $c_1 < C_1$ , a shortage of aggregate demand depresses output in a recession.

When interest rates are fixed at the zero lower bound  $c_1 < C_1$ , this first order condition implies that reducing the demand shortage at time 1 requires either  $Eu'(c_2)$  or  $v'(d)$  to decrease. To reduce  $Eu'(c_2)$ , a policy in the original zero lower bound analysis of (Krugman 1998) is to commit at time 1 to stimulating future demand by keeping interest rates below their natural level, which is called forward guidance. This is not considered in my model since we are in an endowment economy where  $c_2$  is held fixed for simplicity. A second policy considered here is to reduce  $v'(d)$  by either increasing the supply of safe assets. A shortage of aggregate demand due to a scarcity of safe assets is termed a "safety trap" by (Caballero Farhi 2017), and the stimulating effects of reducing the scarcity of safe assets in my analysis is similar to what they show. The three comparative statics considered above all change the safety premium  $v'(d)$  and therefore influence aggregate demand when the zero lower bound constrains conventional interest rate policy.

The novelty of my analysis is that it considers how changing the scarcity of safe assets leads to changes in the portfolio choices of financial intermediaries and the leverage of the financial and non-financial sectors. This allows me to understand the effects of quantitative easing on financial stability, which has worried some policymakers. Relatedly, (Stein 2012b) is a policy speech arguing that debt issuance by the non-financial sector in order to repurchase stock could possibly weaken the effects of quantitative easing, and my model's determination of non-financial capital structure allows me to speak to this concern.

The fact that the equilibrium of my model is characterized by equation 17 makes it quite tractable to analyze the effects of nominal rigidities, since  $c_1$  does not appear in this expression at all. This single equation can be used to solve for all corporate capital structure decisions and the assets and liabilities of the financial intermediary and yields the same answer with and without nominal rigidities. Changes in the supply and demand for safe assets and central bank asset purchases have exactly the same effect on intermediary portfolio choices and corporate capital structure decisions whether or not nominal rigidities cause a shortage of aggregate demand at time 1. This is summarized in the following proposition. One particularly important implication is that asset purchases reduce risk taking by financial intermediaries, since the policy discussion about asset purchases has considered their financial stability implications.



**Proposition 12** (*irrelevance of nominal rigidities for portfolios and capital structure*) *The leverage decisions of the intermediary and non-financial sector, the portfolio choice of the intermediary, the intermediary's marginal cost of equity  $C'(e)$ , and the safety premium  $v'(d)$  have the same response to asset purchases or changes in the supply and demand for safe assets with or without nominal rigidities. The results proved above for changes in these variables continue to hold at the zero lower bound.*

Because the changes in  $v'(d)$  computed without nominal rigidities continue to hold, it is immediate to determine the effect of the comparative statics considered above on consumption at time 1. This is true because when  $i_d = 0$  it must be the case that for any perturbation  $\mu$

$$\frac{\partial c_1}{\partial \mu} u''(c_1) = \frac{\partial u'(c_1)}{\partial \mu} = \frac{\partial v'(d)}{\partial \mu} \quad (35)$$

to ensure the risk-free rate remains at 0. Since  $u'' < 0$ , it follows that any decrease in the safety premium  $v'(d)$  must also increase time 1 consumption.

**Proposition 13** (*the safe asset premium and aggregate demand*) *While at the zero lower bound, increasing the demand for safe assets reduces consumption at time 1 while increases in the supply of safe assets or risky asset purchases financed by the issuance of government debt increase consumption at time 1.*

The response of asset prices to asset purchases or safe asset supply and demand changes does depend on whether there are nominal rigidities. The risk-free rate is held fixed at the zero lower bound while previously it was free to adjust and ensure the goods market at time 1 is able to clear. In addition, increasing aggregate demand at time 1 reduces the marginal utility of consuming  $c_1$ , providing an additional mechanism that boosts asset prices only in a shortage of aggregate demand. The price of an equity security paying  $\delta_e$  at time 2 now changes as

$$\frac{d}{d\mu} E \frac{u'(c_2)}{u'(c_1)} \delta_e = (Eu'(c_2) \delta_e) \frac{-1}{(u'(c_1))^2} \frac{\partial u'(c_1)}{\partial \mu} = (Eu'(c_2) \delta_e) \frac{-1}{(u'(c_1))^2} \frac{\partial v'(d)}{\partial \mu} \quad (36)$$

while the price of a debt security paying  $\delta_{debt}$  now changes as

$$\begin{aligned}
& \frac{\partial}{\partial \mu} \left[ E_{bad} (\delta_{debt}) (1 + i_d) + \frac{1}{2} \frac{u' (c_2^{good})}{u' (c_1)} (1 - C' (e)) (E_{good} - E_{bad}) \delta_{debt} \right] \\
&= \frac{1}{2} \left[ \frac{u' (c_2^{good})}{u' (c_1)^2} \left( -\frac{\partial v' (d)}{\partial \mu} \right) (1 - C' (e)) + \frac{u' (c_2^{good})}{u' (c_1)} \left( -C'' (e) \frac{\partial e}{\partial \mu} \right) \right] (E_{good} - E_{bad}) \delta_{debt}.
\end{aligned} \tag{37}$$

Relative to the equity market, the debt market has no change in risk-free rate but a greater proportional change in the price of systematic risk due to the additional effect of changing  $C' (e)$ . This is because asset purchases only effect the pricing of risk in the equity market through the indirect effect on consumption, while the pricing of risk in the bond market depends explicitly on the intermediary's cost of equity capital as well as on consumption. These calculations prove the following proposition.

**Proposition 14** (*asset price responses at the zero lower bound*) *At the zero lower bound,*

- (i) *An increase in the demand for safe assets reduces the prices of debt and equity securities.*
- (ii) *An increase in the supply of safe assets increases the prices of debt and equity securities.*
- (iii) *Purchasing risky assets financed by the issuance of riskless government debt increases the prices of debt and equity securities. The risk-free rate implied by equity prices decreases while the risk-free rate implied by bond prices remains at zero. The price of risk in both markets decreases, with a greater proportional decrease in the debt market.*

Of particular interest, asset purchases now lower the cost of borrowing for the non-financial sector, since the risk-free rate stays fixed and the price of systematic risk decreases with asset purchases. This is related to the verbal argument (Stein 2012b) gives in a policy speech that asset purchases may induce firms to borrow in order to repurchase stock as a result of their decreased borrowing cost. My model provides a particularly relevant framework for evaluating this reasoning, since unlike in existing models it is the relative cost of debt and equity financing that determines the leverage of the non-financial sector in my framework. Consistent with event study evidence (Neely 2011, Chodorow-Reich 2014), at the zero lower bound asset purchases boost both debt and equity prices, and it is the relative cost of debt and equity financing that determines optimal capital structure. As a result, the non-financial sector may decrease

its leverage despite the reduced borrowing cost, as characterized in the section without nominal rigidities. One limitation of my analysis is that it only formalizes a broad "portfolio balance" channel in which all debt securities are priced by preferences of the same intermediary, while there is some empirical evidence (Krishnamurthy Vissing-Jorgensen 2011) that segmentation between markets for individual assets plays an important role in the transmission mechanism of quantitative easing.

**Conclusion** This paper develops a general equilibrium model of how the financial system is organized to meet a demand for safe assets. In the model, financial intermediaries face the same financing frictions as other firms and have the same information and investment opportunities as households. The role played by intermediaries is to pool the debt of non-financial firms, who cannot issue riskless assets because of idiosyncratic risk, and issue riskless securities and a risky equity tranche backed by this debt portfolio. The debt and equity markets are endogenously segmented, and the non-financial sector's optimal capital structure arbitrages these segmented markets. While previous models of financial intermediation emphasize the illiquidity of intermediary balance sheets, this model provides a framework that can explain intermediaries' large holdings of liquid, publicly available securities. In addition, the model shows how a growing demand for safe assets causes a subprime boom and provides a framework for understanding the transmission mechanism of quantitative easing policies and their implications for financial stability.

Several features of the model suggest a future research agenda. First, the model takes as given the demand for safe, money-like assets. A more fundamental framework where the demand for money and the role of intermediaries as creators of money are both endogenous may provide additional insights. Second, existing safe assets are typically denominated in a currency. A framework with safe assets in multiple currencies may be useful for understanding the international spillovers of quantitative easing and the role of the dollar in the international financial system. The perspective taken in this model, where the demand for liabilities issued by intermediaries determines their asset portfolio, may be a useful and tractable framework for many questions about the role of intermediaries in macroeconomics and finance.

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**Appendix:Proof of proposition 4** This appendix proves that firms optimally issue debt and equity securities and provide enough compensation to management that they do not divert resources. The firm sells securities before its cashflows  $f_i$  are privately observed by its management. Because there are only two types of investors, without loss of generality the firm only issues one non-equity security. These securities can have payoffs that depend on the residual cashflows  $x_i$  that remain after management has been compensated but not directly on the uncontractible aggregate good or bad state. I first take as given the securities the firm issues and study its optimal compensation of management and then solve for its optimal security issuance.

Suppose the firm has issued a security paying  $s(x_i)$ , depending only on the residual cashflows  $x_i$ , leaving the residual claim  $x_i - s(x_i)$  for the firm's equityholders. Equityholders provide compensation to management in order to maximize the value of their residual claim. In general, such a compensation contract can be represented by a mechanism with message space  $M$ , so the payment to management is a function  $R : M \times X \rightarrow \mathbb{R}^+$  where  $x \in X$  is the cashflows remaining after management diverts resources. When  $f_i$  is realized and management chooses  $(m_i, x_i) \in M \times X$ , management's payoff is

$$R(m_i, x_i) + C(f_i - x_i) \tag{38}$$

. which is maximized by management's strategy  $[m_i(f_i), x_i(f_i)]$ .

If  $x_i(f_i) = x_i(f'_i)$ , then

$$R(m_i(f_i), x_i(f_i)) + C(f_i - x_i(f_i)) \geq R(m'_i(f_i), x_i(f_i)) + C(f_i - x_i(f_i)) \tag{39}$$

$$R(m'_i(f_i), x_i(f_i)) + C(f'_i - x_i(f_i)) \geq R(m_i(f_i), x_i(f_i)) + C(f'_i - x_i(f_i)) \tag{40}$$

so  $R(m_i(f_i), x_i(f_i)) = R(m'_i(f_i), x_i(f_i))$ . It follows that the message space  $M$  can be ignored and all allocations depend only on  $x_i$ , with management receiving compensation  $R(x_i)$ .

After  $x_i$  is revealed to equityholders, they are able to covertly destroy resources or raise funds and pay them back at the market rate. If  $x_i$  is revealed and equityholders destroy resources, they can reduce  $x_i$

and receive the payoff  $x - s(x)$  for  $x \leq x_i$ . If equityholders raise hidden funding, they can increase  $x_i$  to any  $x > x_i$  but must pay back  $(x - x_i)$  to the outside source of funding, receiving  $(x - s(x)) - (x - x_i)$ . Equityholders therefore choose  $x$  to maximize

$$G_{x_i}(x) = \left( \{x - s(x)\}_{x \leq x_i} \{x - s(x) - (x - x_i)\}_{x > x_i} \right). \quad (41)$$

This menu is pointwise increasing in  $x_i$ , so equityholders find it optimal to induce management to turn over the largest feasible  $x_i$  given  $f_i$ . Because  $C' < 1$ , this occurs when management receives the smallest payment to induce no diversion, which pays  $C(f_i)$  when  $f_i$  is realized<sup>19</sup>. Equity then maximizes

$$\left( \{x - s(x)\}_{x \leq f_i - C(f_i)} \{x - s(x) - (x - x_i)\}_{x_i > f_i - C(f_i)} \right) \quad (42)$$

The optimal  $x(f_i)$  implies the payment to equity is increasing because  $G_{f_i - C(f_i)}(x)$  is pointwise monotone increasing in  $x$ , which is preserved under taking a supremum.

Note that

$$\left| \sup_x G_{f_i - C(f_i)}(x) - \sup_x G_{f'_i - C(f'_i)}(x) \right| \leq |f_i - C(f_i) - f'_i - C(f'_i)| \quad (43)$$

so  $f_i - C(f_i) - e(x(f_i - C(f_i)))$  is increasing as well.

Note also that if  $s(x)$  and  $x - s(x)$  are increasing, it is optimal for equity to neither destroy resources nor raise hidden funding.

It follows that the realized payoffs of securities satisfy  $s(x) + e(x) \leq x$ , and both  $e(x)$  and  $x - e(x)$  are nonnegative monotone increasing.

As a result, equityholders can increase the market value of  $s(\cdot)$  without reducing the payoff to equity by replacing  $s(x)$  by  $x - e(x)$ .

The optimal security issuance therefore satisfies  $s(x) + e(x) = x$ , with  $s$  and  $e$  increasing. Since  $s$  and  $e$  are therefore Lipschitz and thus absolutely continuous and  $s(0) = e(0) = 0$ , there exist functions  $e'$  and

<sup>19</sup>That is,  $R(x_i) + x_i = f_i$  and  $R(x_i) = C(f_i)$ . This system of equations has a unique solution.



$s'$  such that

$$s(f_i - C(f_i)) = \int_0^{f_i - C(f_i)} s'(u') du = \int_0^\infty s'(u) \{f_i - C(f_i) > u\} du \quad (44)$$

$$e(f_i - C(f_i)) = \int_0^\infty e'(u) \{f_i - C(f_i) > u\} du \quad (45)$$

where  $s'$  and  $e'$  are nonnegative and sum to 1.

Each security can therefore be written as a portfolio of assets of the form  $\{f_i - C(f_i) > u\}$ . Since  $\frac{\Pr\{f_i - C(f_i) > u | good\}}{\Pr\{f_i - C(f_i) > u | bad\}}$  is strictly increasing in  $u$ , there exists a cutoff  $u^*$  such that  $\{f_i - C(f_i) > u\}$  is more valuable to the intermediary for  $u < u^*$  and to the household for  $u > u^*$  since the intermediary is willing to pay more than the household only for assets with low enough systematic risk. The optimal security design therefore sells the claim  $\int_0^{u^*} \{f_i - C(f_i) > u\} du = \min(f_i - C(f_i), u^*)$  to the intermediary and  $\int_{u^*}^\infty \{f_i - C(f_i) > u\} du = \max(f_i - C(f_i) - u^*, 0)$  to the household. These are the payoffs of a debt security and an equity security, and because they are both monotone increasing, equityholders will not destroy cashflows or raise hidden funding.