ISSN 0956-8549

Safe Assets as Balance Sheet Multipliers

By

Emre Ozdenoren
Kathy Yuan
Shengxing Zhang

FINANCIAL MARKETS GROUP DISCUSSION PAPER NO. 970

July 2026

Safe Assets as Balance Sheet Multipliers

Emre Ozdenoren
London Business School
CEPR

Kathy Yuan
London School of Economics
FMG
CEPR

Shengxing Zhang*
London School of Economics
CFM CEPR

May, 2021

Abstract

We highlight the multiplier role of (public) safe assets by studying a model of a bank's balance sheet. The bank optimally constructs a portfolio of safe and risky assets and designs its liabilities. Holding costly but adverse-selection-free safe assets multiplies the production of risky assets with information frictions and facilitates the issuance of private safe debts backed by the asset portfolio, expanding the bank's balance sheet. Safe assets' convenient yields can be decomposed into safety and liquidity components. Quantitative easing operations such as safe for troubled asset swaps improve fiscal capacity of governments and are more liquidity effective.

Keywords: Adverse Selection; Collateral; Convenience Yields; Financial Fragility; Narrow banking; QE; Quality-Sensitive Assets; Safe Assets; Safety Premium; Security Design; Shadow Banking.

JEL classification: G10, G01

*Ozdenoren (eozdenoren@london.edu), Yuan (k.yuan@lse.ac.uk), and Zhang (s.zhang31@lse.ac.uk). We thank William Diamond, John Moore, Christine A. Parlour, Guillaume Rocheteau and seminar participants at the London School of Economics, LBS, the Coller School of Management, UPF, Fudan University, Madison Money Workshop (2020), WFA (2020) and FIRS (2021) for valuable comments.

1 Introduction

It has been a long standing puzzle why U.S. corporations hold seemingly excessive amounts of safe assets including cash and tradable treasury securities. According to *Is There a U.S. High Cash Holdings Puzzle after the Financial Crisis?* (2013), the average cash/asset ratio for non-financial and non-regulated firms with a market capitalization above \$5 million per year is approximately 21% from 2004 to 2010 and at least 10% of the cash/asset holding is regarded as excessive. For financial firms, the puzzle is even deeper. For example, in 2007 required reserves in the U.S. banking system averaged \$43 billion, while excess reserves averaged only \$1.9 billion. During the first six months of 2012, required reserves averaged almost \$100 billion, while excess reserves averaged \$1.5 trillion.[1] Even unregulated shadow banks hold large amounts of safe assets. Jiang et al. (2020) show that for shadow banks active in the U.S. mortgage market, cash and cash-like securities constitute, on average, 15% of their total assets in the 2011–2017 period. Moreover, the demand for safe assets in the form of reserves, treasury bills and bonds issued by the government has been time-varying. For example, Andolfatto and Spewak (2018) have documented that the share of safe assets–outstanding U.S. Treasury securities (treasuries)–was at a stable rate of 35% of GDP throughout early 2000, but has increased to 75% since the 2007–2008 crisis, thereby indicating that demand for safe assets is especially important during crisis periods. To explain the demand for safe assets, we develop a model that formalizes the role of publicly issued safe assets as a balance sheet multiplier in an economy with adverse selection, complementing the existing roles of safe assets as a medium of exchange, a unit of account and a store of value.[2] Specifically, we demonstrate that publicly issued safe assets facilitate more asset production on the asset side and/or promote high leverage on the liability side of the balance sheet of private, especially financial, firms.

Before pinpointing the multiplier role of safe assets, we first model the optimal balance sheet composition of a representative borrower who faces a limited commitment problem. In this case, the borrower has to pledge cash flows from the asset side of her balance sheet as collateral to secure funding from investors (which are listed as liabilities on her balance sheet) to realize gains from trade. Typically, borrowers can produce/purchase two types of assets as collateral: risky credit instruments (e.g., mortgage and corporate loans), and safe assets (e.g., treasury or equivalent securities). Risky collaterals have limited funding capacity due to adverse selection. To model adverse selection, we assume that

[1] https://www.frbsf.org/education/publications/doctor-econ/2013/march/federal-reserve-interest-balances-reserves/

[2] For example, Samuelson (1958) studies money as a store of value in an overlapping-generations model, Kiyotaki and Wright (1989) study money as a medium of exchange in a model with search frictions, Doepke and Schneider (2017) analyze money as a unit of account for an optimal currency area where firms manage relative price risks among trading partners.

the risky collaterals have either high or low quality, and this information is privately observed by the borrower. Safe assets, on the other hand, are free from information frictions but costly to produce by the government and, therefore, expensive for investors to hold.

When the borrower is restricted to using risky collateral on the asset side of the balance sheet and sell an equity claim backed by it on the liability side of the balance sheet to raise funding, the equilibrium outcome depends on the degree of adverse selection. When the degree of adverse selection is severe, borrowers with high-quality collaterals would choose not to be pooled with those with low-quality collaterals. As a result, the market for collateralized borrowing is full of lemon assets, the prices for the equity claims are low and less funding is raised, resulting in a small balance sheet for the borrower. The opposite is true when the adverse selection is mild: that borrowers with both quality types of collaterals are selling equity claims and investors are willing to pay a high pooling price resulting in a large balance sheet size.

In this lemons environment, we demonstrate that safe assets act as a balance sheet multiplier. In reality, safe assets are costly to hold for investment (e.g., due to inflation). To starkly highlight the balance sheet multiplier role of the safe asset, we first study the case where the cost to secure a unit of safe asset is higher than the gain from trade directly generated by it. Hence, it is not profitable to hold safe assets on their own. An immediate consequence of this assumption is that safe assets are not desirable if risky collaterals are already sold in a pooling equilibrium at a high pooling price. However, if risky collaterals are sold in the separating equilibrium, we show that safe assets improve the funding environment. By holding both safe assets and risky collaterals on the asset side of the balance sheet, adverse selection of the combined asset portfolio is reduced, the economy switches from the separating to the pooling equilibrium, resulting in more funding, a larger balance sheet, and greater realized gains from trade.[3]

Consequently, borrowers are willing to pay more to construct a portfolio of both safe assets and risky collateral on their balance sheets, leading to high valuations for both asset types. Moreover, both asset types complement each other. When the cost of holding the safe asset is lower, more of the risky collateral asset will be held, which means the borrowers' balance sheet expands and pledgeable cash flow in the economy increases. That is, safe assets facilitate the risky collateral production on the balance sheet and act as a collateral multiplier. This finding is supported by the empirical evidence in Adrian and

[3]This theoretical result is consistent with the finding in Peydró, Polo, and Sette (2021) where by studying the balance sheet compositions of Italian banks during 1999–2013 they find that during times of crisis (that is, when the adverse selection problem is severe), banks switch to hold safer securities instead of making risky (collateral) loans.

Shin (2014) where they document the expansion of bank balance sheets as monetary policy is loosened.

Next, we allow borrowers to optimally design both the asset and liability sides of the balance sheet jointly. In our setting, optimal security design leads to tranching the liability into a debt tranche that is issued by both high- and low-quality borrowers and, hence, sold at a pooling price, as well as an equity tranche issued by only the low type of borrower and sold at a separating price. The debt tranche is a claim to the entire cash flow from the safe assets and the cash flow from the risky collaterals up to a threshold. This threshold is chosen so that high-quality borrowers are indifferent between selling the debt versus not, ensuring that the debt tranche is quality insensitive.[4]

The interesting element of this design is the interaction between the two quality-insensitive instruments that are free from adverse selection: the safe asset on the asset side (produced by the government)–public safe asset–and the debt tranche on the liability side of the balance sheet–private "safe" securities. In this way, our theory applies naturally to banks, especially shadow banks. The asset side of the bank's balance sheet consists of safe assets such as treasury securities and risky assets such as bank loans. The liability side consists of (short-term) debt such as repos and other wholesale securitized products. For this reason, we sometimes refer to the borrowers in our model as banks.

Private safe securities production via debt tranche substitutes for the high cost of holding public safe assets and hence, lowers the funding cost in the economy. Without security design, borrowers need to hold enough safe assets to make the entire asset portfolio quality insensitive. With security design, they are able to reduce costly safe asset holding since only the debt tranche needs to be quality insensitive. All else equal, they hold fewer safe assets per unit of risky collateral, indicating a substitution effect.

At the same time, there is a complementarity between the public safe asset and private safe security holding/production. An increase in the safe asset holding in a lemons market reduces adverse selection, allowing the quality-insensitive debt tranche to expand and the quality-sensitive equity tranche shrink in size. This complementarity between the public safe asset and private safe securities strengthens the aforementioned collateral multiplier effect of the safe assets, because when the cost of safe assets becomes lower, banks not only hold more safe assets and more risky collaterals but also more safe assets per unit of the risky collateral. As a result, the private safe securities–the debt tranche–become larger. The resulting higher leverage incentivizes banks to hold even more risky assets on the balance sheet, causing the balance sheet to grow further. This balance sheet multiplier effect of safe assets in our model corresponds with procyclical leverage and balance sheet size as documented in Adrian and Shin (2014)

[4] We refer to assets and securities sold in a pooling equilibrium as quality insensitive, in a separating equilibrium as quality sensitive.

for the financial intermediation sector of the economy (in particular shadow banks). To summarize, with security design, safe assets facilitate collateral production on the asset side and promote leverage on the liability side of the balance sheet, both strengthening the balance sheet multiplier effect.

This set of theoretical results is in line with empirical observations. For example, when the cost of safe assets increases, our model predicts that banks with loans that are more subject to adverse selection (e.g., banks with a larger fraction of subprime mortgages) would shrink their balance sheet further and decrease their leverage more. Going back to the safe asset puzzle presented at the beginning of the introduction, our model of the optimal balance sheet potentially explains why banks (or firms) hold excessive cash or cash-like assets on their balance sheet (and borrow at the same time). According to our model, the extraordinary level of safe asset holdings in the banking system since 2008 is the equilibrium response to the reduction in the cost of safe assets from quantitative easing (QE), and the existence of severe adverse selection problem in the banking system during and after the 2008 Great Recession. Our theory also finds empirical support in Ennis and Wolman (2015). They have shown that a significant proportion of reserves were held by banks apparently not restricted by capital requirements. Instead, they find reserves did not crowd out other kinds of banking assets (such as securities, loans, and leases) and banks with more reserves have larger balance sheet capacity.

Thus far, to illustrate the complementarities between public and private safe assets, we have assumed that the gains from trade are linear in the amount of funding. Next, we generalize the model in a setup where there are many bankers and the gains from trade are concave in the amount of funding in the economy, a natural assumption akin to decreasing return to scale technology. This generalization allows us to characterize conditions under which public safe assets are complements vs. substitutes with private safe debt. We show that when the gains from trade are high, additional safe assets lower the adverse selection on banks' asset portfolios and hence allow them to produce more private safe debts on the liability side and hold more risky collaterals on the asset side of the balance sheet. Empirically, this corresponds to the scenario where the economy faces greater uncertainty (either new technologies or large negative shocks inducing potential large gains from trade) and limited funding, resulting in procyclical leverage and balance sheet size as documented in Adrian and Shin (2014). However, when the economy is flooded with funding, the gains from trade are small, and additional safe assets further diminish marginal gains from trade. High-quality borrowers become less willing to borrow at the pooling price. As a result, banks lower their debt threshold, leading to lower private safe debt creation and lower leverage. Empirically, in this scenario the amount of net private debt (private debt minus treasury) is negatively correlated with the size of public safe assets (i.e., treasury), as documented by Krishnamurthy and Vissing-Jorgensen (2015), indicating that public safe assets crowd out private safe debt creation.

The generalization of our model allows us to study the role of (conventional) monetary policy in creating liquidity in the economy across business cycles. At the initial rise and the bottom of the business cycle, adverse selection is severe and the complementarities between publicly safe asset and private safe debt are dominant. Monetary policy can utilize this complementarity by issuing treasuries to encourage private debt creation. During the peak of the business cycle, adverse selection is low. The substitution effect dominates, and monetary policy needs to be more conservative ito avoid inefficient crowding out of private debt.

With this new perspective that safe assets are balance sheet multipliers, we explore the implications of unconventional monetary policies during the crisis. We find that when adverse selection in the private sector's balance sheet is severe, it is optimal for the government to conduct unconventional monetary policies similar to the large scale asset purchase program (LSAP) or the troubled asset relief program (TARP) of the U.S. government in 2008 that swapped 'troubled" private risky assets for treasuries. An alternative policy would involve the central bank injecting safe assets directly into banks and leaving the troubled assets on banks' balance sheets. This alternative requires the central bank to supply many more safe assets backed by greater tax revenues to attract the same level of investment in the economy, demanding a large fiscal capability and potentially negative profits for central banks. According to our theory, asset swaps are more effective in stimulating economic growth because government has an informational advantage relative to private lenders: it can remove troubled assets from bank balance sheets without suffering from the adverse selection problem. It can then inject safe assets into the private sector's balance sheet using a combination of payments from risky assets and taxation. Our analysis of central bank intervention yields one new cross-sectional testable implication: credit spreads of long-term credit instruments (such as mortgage or corporate bonds) largely reflect the fiscal capability of the corresponding government.

Finally, we study the pricing implications of safe assets. In our model, all public safe assets earn a liquidity premium due to the role of the balance sheet multiplier. However, even though publicly issued safe assets are free from adverse selection, their payoff might be deterministic. There are multiple reasons why safe assets such as treasury bonds might not be completely risk-free. First, the coupon payments from treasuries are nominal and subject to inflation risk. Second, treasuries not only pay a cash flow but also a service flow. The service flow could be based on the corresponding collateral rent, which is time varying and risky. In our model, due to its role as balance sheet multiplier, safe assets command a price premium. However, the multiplier effect is larger when the safe asset's payoff is risk-free. By modeling safe assets with a risky payoff component allows us to decompose the price premium or convenience yield for safe assets into two components–safety and liquidity– and speak to the empirical literature. For example, Krishnamurthy and Vissing-Jorgensen (2012) show that during the sample period of 1926–2008, the liquidity attributes of treasuries account for 46 basis points, while the safety attributes of treasuries account for 26 basis points per year in terms of convenience yield. This decomposition varies with the level of adverse selection, costs of safe assets with different risk profiles, gains from trade arising from productivity in the economy.[5]

Literature Review

The economics of safe assets has fascinated the economic profession due to its interesting features and pricing anomalies (Gorton (2016)). Caballero and Farhi (2017) and Caballero, Farhi, and Gourinchas (2017) define a safe asset as a simple debt instrument that is expected to preserve its value during adverse systemic events. Brunnermeier and Haddad (In Preparation) also define safe assets as assets that appreciate in value in times of stress but point out the bubble aspect of safe assets. Safe assets in our paper are defined as being free of information frictions, similar to the definition of safe assets as information-insensitive securities in Dang, Gorton, and Holmström (2013). Gorton and Ordonez (2013b) show that public safe assets play an important stabilizing role in collateral production, irreplaceable by private assets such as bank loans. Our model formalizes the role of public safe assets played in lowering the adverse selection and stimulating collateral production in the economy. The underlying economic mechanism is different as the frictions in our model lead to adverse selection rather than incentives to acquire information. By formulating the role of safe assets as a balance sheet multiplier, our model has implications for the effectiveness of various unconventional monetary policies. Our models shows that QE operations that take the troubled assets off banks' balance sheets are most effective when adverse selection is severe and fiscal capacity of government is limited. This speaks to the literature that assesses the impact of QE on not only a wide range of financial assets but also financial markets in general (Krishnamurthy and Vissing-Jorgensen (2011), Haldane et al. (2016), and Reis (2017)).

Our theoretical finding of the interaction between the supply of public safe assets and the production of private liquid debt adds an additional complexity to the finding that public safe assets and private safe assets are substitutes as shown in Krishnamurthy and Vissing-Jorgensen (2015), Gorton, Lewellen, and Metrick (2012), Gorton and Ordonez (2013b), and Carlson et al. (2016) This literature focuses on the money view of both public and private safe assets: both provide direct utility for consumers and

[5] Geromichalos, Herrenbrueck, and Lee (2018) also distinguish safety and liquidity premium. In their setup, not all safe assets are liquid.

are substitutes for providing short-term liquidity. We also emphasize a collateral view , that public safe assets act as collateral multipliers and lower the adverse selection in the banking sector's balance sheet. This view is consistent with the empirical findings on both short-term and long-term safe asset production. For example, the balance sheet channel of safe assets is observed by Kacperczyk, Perignon, and Vuillemey (2021) where they show that European banks that have higher quality balance sheets are able to issue more short-term CDs (i.e., private safe debts), which are better substitutes for short-term government securities from 2008–2014. Regarding the long-term safe assets, our theory predicts that they can act as complements to risky assets, especially during times of crisis. This theoretical insight is consistent with the findings in Krishnamurthy and Vissing-Jorgensen (2012) that show that the liquidity premium on long-term treasury bonds was substantially higher than T-bills at the time of Operation Twist, indicating the contraction of long-term safe collaterals that negatively affected the value of long-term risky assets, leading to increased mortgage spreads. Our theory, nevertheless, generates both substitution and complementary effects, accommodating both money and collateral views of public and private safe asset interactions. We find that borrowers optimize on both public and private liquidity margins: when the cost of public safe assets is relatively high, borrowers indeed substitute toward private liquidity per unit of risky collateral; however this crowding out effect is subtle and takes place when there is a large enough supply of safe assets in a lower adverse selection environment. When the cost of the safe asset is relatively low and the supply is limited, an additional holding of safe assets would lead to more production of private liquid short-term debts. Our finding on this complex interaction of public and private liquidity production potentially could shed light on the impact of unconventional monetary policies on the role of banks in producing "money-like" short-term liquid securities. This role has been well recognized in both the macro and the banking literature (Diamond and Dybvig (1983);Gorton and Pennacchi (1990); Holmstrom and Tirole (1998) Stein (2012); Diamond (2017); and Donaldson, Piacentino, and Thakor (2018)), while how the supply of public safe assets affects private liquidity production and hence entrepreneurial activities/real output in this type of economic environment has been understudied.

Moreover, our model produces new pricing implications of safe assets. In our model, borrowers are willing to hold and pay more for safe assets due to their balance multiplier effect and the resulting convenience yield can be decomposed into liquidity and safe components. These theoretical findings are supported by empirical results in Krishnamurthy and Vissing-Jorgensen (2012) and recent work by Jiang et al. (2019) that show that the market value of outstanding government debt is significantly above the expected present discounted value of current and future primary surpluses.

Our paper is also related to a long lineage of security design literature including Leland and Pyle (1977); Myers and Majluf (1984b); Nachman and Noe (1994);DeMarzo and Duffie (1995);DeMarzo and Duffie (1999) Biais et al. (2007); and Chemla and Hennessy (2014). By focusing on liquid debts, our paper is also related to endogenous asymmetric information in an optimal security design problem such as Rocheteau (2011); Yang (Forthcoming); Dang, Gorton, and Holmström (2013); and Farhi and Tirole (2015). The fact that information friction affects the moneyness of an asset has also been studied by Lester, Postlewaite, and Wright (2012) and Li, Rocheteau, and Weill (2012a). Our focus on the interaction between the public and private liquidity design is unique to this literature.

Our model shares several features of an earlier paper by Bigio and Weill (2016) who study banks' optimal asset-liability design. Bigio and Weill (2016) model the frictions between a monopolistic bank and producers who own informative-sensitive assets in a two-state economy. They focus on the intermediary role of banks in creating deposits for the productive sectors of the economy by pooling information-sensitive assets, and show that liquid and illiquid assets are complementary in deposit creation. In our model, we abstract away the difference between banks and producers and consider them as a coalition. Instead, we focus on modeling the role of public safe assets where the demand for public safe assets is a choice variable of borrowers/banks, and the supply of public safe assets is bounded by the fiscal capability of the government. We generalize the state space for both safe and potentially lemon assets, as well as the gains from trade. This allows us to study the pricing of both information sensitive and insensitive assets, such as the safety and liquidity premium of safe assets as well as the credit spread of potential lemon assets, delineate the complementarity or substitution effect between public safe assets and private safe securities, and analyze the effectiveness of conventional and unconventional monetary policies such as QE in an adverse selection environment.

2 The Model

2.1 The Model Setup

There are three dates, $t = 0, 1, 2$ and a single consumption good. The consumption good must be consumed during the date at which it is produced, otherwise it perishes. There are two types of agents which we call agent Bs (borrowers or banks) and agent Is (investors). All agents consume at dates 1 or 2 (but not at date 0). Agent Is are indifferent between consuming an additional unit at date 1 versus at date 2. Agent Bs are more impatient than agent Is. They are indifferent between consuming an additional unit at date 1 versus $z > 1$ additional units at date 2. The reasons that agent Bs are more impatient and need consumption goods at date 1, is possibly because they have higher discount rates or they have access to alternative investment opportunities that produce z units of consumption good at date 2 from each unit of consumption good at date 1. Depending on the application, consumption goods at date 1 can be interpreted as capital or intermediate input for a high-return z-technology, which we discuss in section 2.2. Consequently, there are potential gains from trade between the two types of agents at date 1.

Basic Production Technology. Both types of agents are able to produce the consumption good using labor with a constant returns-to-scale technology such that one unit of consumption good requires one unit of labor. We assume that agent Is can produce the consumption good at all dates whereas agent Bs can only produce it at dates 0 or 2 but not at date 1, which reflects the need for borrowing by agent Bs at the interim date. We also assume that producing the good using labor and consuming it provides zero net utility to both types of agents.

Pledgeable Assets. We assume that agent Bs cannot borrow from agent Is at date 1 unless they make a credible promise to pay back. This assumption could be motivated several ways. If gains from trade are due to different discount rates, agent Bs would consume all the consumption goods that they borrow at date 1. So they need pledgeable cashflow to pay back at date 2. Alternatively, if gains from trade are because agent Bs have productive investment opportunities, i.e., agent Bs produce z units of consumption goods for each unit that they borrow at date 1, there is a limited commitment problem, that is, they cannot commit to pay back loans out of the z units they produce and need pledgeable cash flow to borrow.

There are two types of collateral assets: safe and risky. A safe asset, s, generates $s(\omega) \geq 0$ units of pledgeable consumption good in state ω at time 2 where $\omega \in \Omega$ is the aggregate state of the economy. Suppose that there is a finite number of aggregate states, $|\Omega| = N < \infty$, $\Pr(\omega) = \pi_\omega$, which is commonly known by all agents.[6] We denote the expected value of the safe asset s by $Es = \sum_{\omega \in \Omega} s(\omega)\pi_\omega$ We interpret these assets as government issued safe assets such as treasury bills and bonds whose payoff depends on the aggregate state of the economy. Safe assets may have different risk profiles (e.g., inflation risk at different durations) but are free of information frictions since none of the agents have private information about them. We assume that the market for safe assets is complete and hence there are N

[6]To make a clean comparison, we assume that safe assets are completely free from asymmetric information. In a dynamic framework, the distinction between the safe and risky assets may be less stark. For example, treasury bills and bonds may be subject to short-lived asymmetric information, in contrast to risky assets that are subject to long-lived asymmetric information.

Arrow-Debreu assets which we denote by s_ω for $\omega \in \Omega$ such that $s_\omega(\omega) = 1$ and $s_\omega(\omega') = 0$ for $\omega' \neq \omega$.[7]

We also assume that there are N risky assets $r_\omega : \Omega \times [\underline{\theta}, \overline{\theta}]$ for $\omega \in \Omega$. We assume that $r_\omega(\omega', \theta) = 0$ for $\omega' \neq \omega$ and $r_\omega(\omega, \theta) = r_{\omega'}(\omega', \theta) = \theta$ for all $\theta \in [\underline{\theta}, \overline{\theta}]$ and $\omega, \omega' \in \Omega$. These risky assets are similar to Arrow-Debreu assets in the sense that they only pay in one of the aggregate states; however, they are risky because their payoff depends on the realization of another random variable θ. The distribution of θ is given by $F_Q(\theta; \omega)$ which depends on the quality of risky assets, Q, and the aggregate state of the economy ω. Agent Bs have *private information* about the quality Q, which can be high (H) or low (L). This formulation allows θ and ω to be correlated and the degree of adverse selection to depend on the state of the economy ω. We denote the expected value of a risky asset r_ω with quality Q in state ω by $E_Q^\omega \theta = \int \theta dF_Q(\theta; \omega)$. Agent Is believe that L occurs with probability λ and H occurs with probability $1 - \lambda$, and this, as usual, is common knowledge. We refer to an agent B that observes quality Q as type Q borrower/bank. We interpret risky assets as privately issued assets such as mortgage or corporate loans.

Although many of our results can be illustrated in a single ω-state setup, the more general environment is important in decomposing the safe asset premium into its safety and liquidity components. In addition, this setup clarifies the distinction between safe and risky assets and opens the door to studying the implications of market incompleteness on the value of safe assets.

Safe Asset Markets and Risky Asset Production. Markets for safe assets open up at date 0. We assume that the date 0 price of Arrow-Debreu safe asset s_ω is p_ω. By no arbitrage, price of safe asset s is $p(s) = \sum_\omega s(\omega) p_\omega$. We can think of markets for safe assets as treasury auctions or secondary markets. Similarly, date 0 price of A units of the risky asset r_ω is $p(A; r_\omega)$ units of consumption good with $p(0; r_\omega) > 0$, $p'(A; r_\omega) \geq 0$, $p''(A; r_\omega) \geq 0$ for all $A > 0$. Agent B pays for safe and risky asset purchases by producing the consumption good via labor at date 0.

Securities. Next, we define the securities backed by the pledgeable cash flow of a portfolio consisting of M_ω units of the safe asset s_ω and A_ω units of the risky asset r_ω for $\omega \in \Omega$. At date 1, agent Bs use these securities to trade with agent Is in securities markets that we describe later.

A security $y : \Omega \times [\underline{\theta}, \overline{\theta}] \rightarrow \mathbb{R}_+$ is a payoff contingent contract.[8] The contract is fulfilled at date 2 when assets pay dividends. We assume that securities are monotone in the dividends generated by the assets:

$$y(\omega, \theta) \geq y(\omega, \theta') \text{ if } M_\omega + A_\omega \theta \geq M_\omega + A_\omega \theta' \tag{1}$$

[7] That is, we assume that existing safe assets span the aggregate states.

[8] We restrict attention to right continuous contracts.

for all $\omega \in \Omega$ and $\theta, \theta' \in \left[\underline{\theta}, \overline{\theta}\right]$.

A *security design* is a finite set of securities, $\mathcal{J} = \left\{y^1, \cdots, y^J\right\}$, backed by M_ω units of the safe asset s_ω and A_ω units of the risky asset r_ω for $\omega \in \Omega$, that is,

$$\sum_{j=1}^{J} y^j(\omega, \theta) \leq M_\omega + A_\omega \theta \tag{2}$$

for all $\omega \in \Omega$ and $\theta \in \left[\underline{\theta}, \overline{\theta}\right]$.

Security Markets. The securities are sold in dedicated over-the-counter markets at date 1 after the aggregate state, ω, becomes public information and agent Bs obtain private information about the risky asset's quality. In each security market, several investors make bids à la Bertrand and the seller–the asset owner–decides how much to sell at the highest bid.[9] We denote the price of security y^j in state ω by $q^j(\omega)$, and the quantity of security j exchanged when the underlying asset quality is Q by $a_Q^j(\omega)$.[10] We further assume that an investor has access only to one security market so that trading information is segmented across security markets.

Balance Sheet Design Problem. Since all borrowers are identical, we call a representative borrower agent B in the remainder of the paper. Agent B designs the balance sheet at $t = 0$ before the arrival of information about the aggregate state ω or risky asset's quality Q. Agent B first chooses M_ω (the amount of safe asset s_ω) and A_ω (the amount of risky asset r_ω) for each $\omega \in \Omega$ to hold on the asset side of the balance sheet. At the same time, she chooses the set of securities on the liability side of the balance sheet backed by these assets. At the beginning of date 1, all agents learn the aggregate state ω and agent B learns the risky asset's quality Q. Agent B exchanges some of the securities with date 1 consumption good with agent Is and retains the rest on her balance sheet. Hence, formally, agent B chooses M_ω and A_ω for $\omega \in \Omega$ and a balance sheet design $\mathcal{J}$ taking the security prices $q^j(\omega)$, and

[9] If several investors are tied for the highest bid, agent B equally splits the amount she would like to sell between them.

[10] The price of the security does not depend on the underlying asset quality because investors are not able to distinguish between low and high quality when they make offers for a security; however, the quantity exchanged depends on the quality because the owner is privately informed.

quantities, $a_Q^j(\omega)$, as given to maximize:

$$\sum_{\omega\in\Omega}\left\{\lambda\left[\int_{\underline{\theta}}^{\bar{\theta}}\left(\sum_{j=1}^{J}a_L^j(\omega)\left(zq^j(\omega)-y^j(\omega,\theta)\right)+\left(M_\omega+A_\omega r(\theta)\right)\right)dF_L(\theta;\omega)\right]\right. \tag{3}$$
$$\left.+(1-\lambda)\left[\int_{\underline{\theta}}^{\bar{\theta}}\left(\sum_{j=1}^{J}a_H^j(\omega)\left(zq^j(\omega)-y^j(\omega,\theta)\right)+\left(M_\omega+A_\omega r(\theta)\right)\right)dF_H(\theta;\omega)\right]\right\}\pi_\omega$$
$$-\sum_{\omega\in\Omega}p\left(A_\omega;r_\omega\right)-\sum_{\omega\in\Omega}M_\omega p_\omega$$

The balance sheet design takes place ex-ante before the arrival of information about the aggregate state or the quality of the risky asset. We have in mind an environment where risky assets (mortgages, corporate loans, etc.) look identical ex ante.

Timeline. To recap, there are three dates. At date 0, agent B chooses the amount of collateral assets to purchase and the composition of the balance sheet. On the asset side, she chooses the amount of safe and risky collateral assets to hold. On the liability side, she chooses the set of securities backed by these assets. After these decisions are made, the aggregate state becomes public information and agent B privately learns the quality of risky collateral assets on the balance sheet. At date 1, agent Is and agent Bs trade securities: Agent Is exchange consumption good for the securities issued by agent Bs backed by the assets on their balance sheets. At date 2, agent Bs make payments promised by securities to agent Is based on the realization of the state.

2.2 Applications

In our leading application of the model, agent Bs are shadow banks and the input from agent Is is capital. The representative bank designs the (pledgeable) asset and liability composition of its balance sheet to increase its capacity to raise capital. The asset side of the bank's balance sheet can be broadly categorized into two types: safe and risky. Safe assets are reserves, treasuries and AAA-rated bonds. Risky collaterals are mortgages, car loans, and other collateral-backed debt that the bank issues and has private information about. The liability side of the bank's balance sheet consists of securities backed by these pledgeable safe and risky collateral assets. This interpretation corresponds well to the shadow bank operation described in Gorton and Metrick (2012a). Shadow banks do not have deposit insurance and have to rely on collateralized borrowing for funding.

Gains from trade could be from the bank's off balance sheet activities such as loans to startups that have no immediate cash flows or activities that provide private benefits to the bank or payment processing fees. Cash flows of these productive activities are not pledgeable.

To summarize, the bank raises capital by selling asset-backed securities (on the liability side of its balance sheet) to investors that it uses to support its productive off-balance sheet activities. In the rest of the paper, we refer to the representative agent B as the bank.

The model applies more broadly to firms that have collateral assets and are in need of intermediate inputs for activities that do not generate pledgeable cash flows. For example, a firm may possess an inalienable productive technology while agent Is supply input to this technology. These inputs can be specialized labor or any other types of intermediate goods. Supply chain finance is one specific example.

Finally, the model also applies to the case where agent Bs and agent Is have different discount rates. Agent Is are savers and agent Bs are those who have been hit by a liquidity shock – in aggregate, a deterministic proportion of agent Bs demand liquidity, similar to the environment proposed by Diamond and Dybvig (1983). However, the focus is different. In Diamond and Dybvig (1983), they focus on the role of banks to pool a population of agent Bs and provide demand deposits to insure against liquidity shocks. In our setup, we focus on the role of collateral assets on a balance sheet in creating pledgeable cash flows.

2.3 Equilibrium in Securities Markets

Before proceeding with solving the main model, we first describe the equilibrium in the market for an arbitrary security y.[11] We assume that investors are strategic and compete à la Bertrand, which ensures that equilibrium in each security market is generically unique. That is, in the market for security y, investors simultaneously make price offers taking into account which types of the borrower would sell the security at that price. Agent B observes these offers and decides how much of the security to allocate to each investor.[12] Due to Bertrand competition, investors make zero surplus in expectation, and the equilibrium price of the security, $q(\omega)$, is equal to the expected value of a unit of security given the quantities sold by each type $a_Q(\omega)$:

$$q(\omega) = \lambda E_L^\omega y(\omega, \theta) + (1 - \lambda) E_H^\omega y(\omega, \theta). \tag{4}$$

Quantities sold by each type must be optimal given the price, i.e., for each $Q \in \{L, H\}$,

$$a_Q(\omega) \in \arg\max_{a \in [0,1]} a \left(zq(\omega) - E_Q^\omega y(\omega, \theta) \right). \tag{5}$$

By (1), the expected payoff of the security when issued by the high type is weakly more than that issued by the low type, i.e., $E_L^\omega y(\omega, \theta) \leq E_H^\omega y(\omega, \theta)$. We define quality ratio R as the ratio of the expected

[11] We now drop the security index j from all the variables to ease the notation.

[12] In this formulation agent B has all the bargaining power, but this is not crucial for any of our results.

value of the security under the low versus the high distribution, i.e., $r_\omega \equiv E_L^\omega y(\omega,\theta)/E_H^\omega y(\omega,\theta)$. As this quality ratio increases, the expected values of the security under the low versus high distribution become closer, and the adverse selection problem becomes less severe.

The next proposition characterizes the equilibrium in the security market.

Proposition 1. *If $r_\omega > \zeta \equiv 1-(z-1)/\lambda z$, in the market for security y the price of the security is $q(\omega) = \lambda E_L^\omega y(\omega,\theta) + (1-\lambda) E_H^\omega y(\omega,\theta)$ and $a_L(\omega) = a_H(\omega) = 1$. If $r_\omega < \zeta$ the price of the security is $q(\omega) = E_L^\omega y(\omega,\theta)$ and $a_L(\omega) = 1$ and $a_H(\omega) = 0$.*[13]

Proposition 1 shows that when the quality ratio r_ω is above the threshold ζ, the adverse selection problem is not too severe, and both types sell the security. In this case, the security price is the pooling price $q(\omega) = \lambda E_L^\omega y(\omega,\theta) + (1-\lambda) E_H^\omega y(\omega,\theta)$. When the quality ratio r_ω is below the threshold, the adverse selection problem is severe, and only the low type sells the security. In this case, the security price is the separating price $q(\omega) = E_L^\omega y(\omega,\theta)$.

We refer to a security that is traded in a pooling equilibrium as a *quality-insensitive security* and one that is traded in a separating equilibrium as a *quality-sensitive security.* A quality-insensitive security commands a high pooling price and hence generates more consumption at time 1 for the borrower than a quality-sensitive one that is traded at a lower separating equilibrium price.

In the remainder of the paper, with the exception of section 6.1 on the safety and liquidity premium of safe assets, we consider the case where there is only a single aggregate state, i.e., $N = 1$, and drop dependence on ω from all the variables. It is straightforward to generalize the results to the case with $N > 1$ states.

3 Narrow Design: Balance Sheet with Only One Type of Asset

Suppose agent B is restricted to hold only safe assets on her balance sheet, a practice known as narrow banking. Let y be a security that promises M units of consumption good at date 2, backed by M units of safe asset s. Safe assets are quality-insensitive, hence the price of y, an equity claim on the safe asset s, is simply $q = M$. By holding M units of s, agent B generates M units of pledgeable cash flow and obtain M units of consumption good at date 1. Hence the value of holding M units of s at date 0 is zM, and agent B chooses M to maximize $(z-p)M$. The optimal holding of s when agent B is restricted to hold only safe assets is $M = 0$ if $p > z$, $M \in [0,\infty]$ if $p = z$, and $M = \infty$ if $p < z$.

[13] When $r_\omega = \zeta$ there are multiple equilibria. In particular, both pooling and separating (and even semi-separating) equilibria are possible. To simplify exposition in this knife edge case, we select the pooling equilibrium.

Next, suppose agent B holds only the risky asset on her balance sheet and does not hold any safe asset. A security that is backed by A units of the risky asset r generates $A\theta$ units of pledgeable consumption good at date 2. By Proposition 1, the price q of the security that is backed by A units of the risky asset r, that is, an equity claim on r, is $q = A\left[\lambda E_L\theta + (1-\lambda)E_H\theta\right]$ if $E_L\theta/E_H\theta \geq \zeta$ and $q = AE_L\theta$ if $E_L\theta/E_H\theta < \zeta$.

Given the price of risky asset $p\left(A; r\right)$, agent B chooses A to maximize $Az\left[\lambda E_L\theta + (1-\lambda)E_H\theta\right] - p\left(A; r\right)$ if $E_L\theta/E_H\theta \geq \zeta$ and $A\left[z\lambda E_L\theta + (1-\lambda)E_H\theta\right] - p\left(A; r\right)$ otherwise. Hence, agent B does not hold a positive amount of A if either

$$p'\left(0; r\right) > z\left(\lambda E_L\theta + (1-\lambda)E_H\theta\right), \tag{6}$$

or

$$z\left(\lambda E_L\theta + (1-\lambda)E_H\theta\right) > p'\left(0; r\right) \geq z\lambda E_L\theta + (1-\lambda)E_H\theta \text{ and } E_L\theta/E_H\theta < \zeta. \tag{7}$$

Under (6), agent B does not hold the risky asset even if the security backed by it is sold in a pooling equilibrium. The more interesting case is given by (7). Under (7), holding the risky asset is profitable if the security backed by it is sold in a pooling equilibrium but not in a separating equilibrium; however, adverse selection is severe enough that the security is sold in a separating equilibrium.

In the remainder of the paper, we restrict attention to the interesting case where $p > z$, that is, the safe asset is expensive to purchase: narrow banking is not profitable, and (7) holds, that is, adverse selection in risky collateral is severe enough that its equity claim is sold in a separating equilibrium. As the analysis above illustrates, in this case, agent B does not hold the safe asset s or the risky asset r on her balance sheet if restricted to hold only one asset type. We demonstrate in the next section that even in this case agent B might nevertheless, hold a portfolio of safe and risky assets and sell securities backed by this portfolio because the security backed by the portfolio is subject to less adverse selection.

4 Portfolio Design: Balance Sheet with Both Asset Types

Suppose that agent B holds a portfolio of M units of the safe asset s and A units of the risky asset r. This portfolio generates $\theta A + M$ units of pledgeable goods at date 2. Let y be a security backed by the cash flow of this portfolio that pays $y\left(\theta\right) = \theta A + M$ at date 2. By Proposition 1, the price of this security is given by $q = M + \left[\lambda E_L\theta + (1-\lambda)E_H\theta\right]A$ if $(AE_L\theta + M)/(AE_H\theta + M) \geq \zeta$ and $q = M + AE_L\theta$ otherwise. Note that $(AE_L\theta + M)/(AE_H\theta + M) \geq \zeta$ if and only if $M/A \geq m^*$ where

$$m^* \equiv \frac{\zeta E_H\theta - E_L\theta}{(1-\zeta)}.$$

The benefit of holding the portfolio (M, A) is

$$V(M,A) = \begin{cases} z\left(M + \left[\lambda E_L\theta + (1-\lambda)E_H\theta\right]A\right), & \text{if } M/A \geq m^*, \\ \left[\lambda z E_L\theta + (1-\lambda)E_H\theta\right]A + (z\lambda + 1 - \lambda)\,M, & \text{if } M/A < m^*. \end{cases}$$

For a fixed A, V jumps upward at $M = m^*A$. Everywhere else it is linear with respect to M, and its slope is less than or equal to z. Since $p > z$, $V(M, A) - pM$ is maximized with respect to M at either $M = 0$ or $M = Am^*$.

Agent B chooses $M \geq 0$ and $A \geq 0$ to maximize $V(M, A) - pM - p\,(A; r)$. Since it is never optimal to produce either asset on its own, there are only two cases to consider: the optimal solution involves either $A = M = 0$ or $A > 0$ and $M = Am^*$. Hence, if the maximum is achieved at some $A > 0$, the optimal risky collateral holding is given by the maximizer of:

$$\begin{aligned} & V(Am^*, A) - pAm^* - p\,(A; r) \\ = {} & z\left(\left[\lambda E_L\theta + (1-\lambda)E_H\theta\right]A + Am^*\right) - pAm^* - p\,(A; r) \end{aligned}$$

The value of the optimization problem is strictly positive since agent B could obtain zero payoff by choosing $A = 0$. Since the objective is concave, the optimal A is strictly positive if and only if

$$p'\,(0; r) + pm^* < z\left(\lambda E_L\theta + (1-\lambda)E_H\theta + m^*\right), \tag{8}$$

and if (8) holds then the optimal holding of risky collateral is given by $\bar{A} > 0$ that satisfies

$$p'(\bar{A}; r) + pm^* = z\left(\lambda E_L\theta + (1-\lambda)E_H\theta + m^*\right). \tag{9}$$

We summarize the discussion thus far in the following proposition.

Proposition 2. *Suppose $p > z$ and (7) hold. Then, agent B does not hold the safe asset s or the risky asset r on its own. If agent B is able to combine both assets in a portfolio and sell a security backed by the cash flow from the portfolio, then she holds strictly positive amounts of both assets if and only if (8) holds. The amount of risky collateral r held by agent B is $\bar{A}$ and the amount of safe assets is $m^*\bar{A}$, where $\bar{A}$ solves (9).*

It is too costly to produce the safe asset on its own if the marginal cost of the safe asset exceeds the value of the pledgeable funding that it generates for the gain from trade, i.e. if $p > z$. It is also too costly to produce risky collateral if only the low type pledges its cash flow in the security market but worth producing if both types pledge the cash flow (condition (7)). In this situation, when the safe asset is combined with the risky collateral, it lowers the adverse selection. To attract the high-type risky collateral holder to participate in selling the security, each unit of risky collateral must be combined with at least m^* units of the safe asset. Hence, the effective marginal cost of producing a unit of risky collateral is increased by the marginal cost of producing m^* units of the safe asset. This is the expression on the left side of (9). The right side is the marginal benefit of pledging the cash flow from a unit of risky collateral (given that both types participate in security trading) and m^* units of the safe asset. The optimal amount of the risky collateral equates the effective marginal cost and marginal benefit.

Next, we construct a simple analytical example to illustrate the result. Suppose $p(A;r) = (\gamma/2)\,A^2 + \chi A$, where $z\,(\lambda E_L s + (1-\lambda)\,E_H s) > \chi \geq z\lambda E_L s + (1-\lambda)\,E_H s$ and $p > z$. Hence,

$$p'(A;r) + pm^* = \gamma A + \chi + pm^*.$$

For p close enough to z, $p'(0;r) + pm^* = \chi + pm^* < z\,([\lambda E_L s + (1-\lambda)E_H s] + m^*)$ and (8) holds. The optimal risky collateral holding is given by:

$$\bar{A} = \frac{z\,(\lambda E_L s + (1-\lambda)E_H s) - \chi - (p-z)\,m^*}{\gamma}.$$

As the example illustrates, there are complementarities in the production of the two assets. As long as the marginal cost of producing the safe asset is not too high, agent B finds it profitable to produce both assets and combine them in a portfolio. If this portfolio approach is not allowed, agent B does not produce either asset. Another way of seeing the complementarities is that, when the marginal cost of producing safe asset falls, more risky collaterals are created.[14]

5 Joint Design of Asset and Liability on the Balance Sheet

In the previous sections, our focus was on the asset side of the balance sheet. On the liability side, we considered a single security backed by the cash flow of agent B's assets. In this section, we allow the optimal joint design of asset and liability composition of the balance sheet. Intuitively, agent B can lower adverse selection by offering, on the liability side of the balance sheet, securities that are free from adverse selection and backed by certain tranches of assets' cash flow. By doing so, agent B reduces the amount of the expensive safe assets that she needs to hold on the asset side of her balance sheet.

[14] This part of our analysis is closely related to Rocheteau (2011).

5.1 Optimality of Debt and Equity

We first analyze the optimal choice of securities given that, on the balance sheet, agent B has M units of the risk-free asset s and A units of the risky asset r. The following observation simplifies the analysis: If two securities y^j and y^k are both sold in the pooling (separating) equilibrium, their sum, $y^j + y^k$, is also a feasible design and sold in the pooling (separating) equilibrium. Moreover, offering the sum of the two securities, instead of the two securities separately, raises the same amount of funding. Hence, without loss of generality, we restrict attention to at most two securities: one that is sold in the pooling equilibrium and the other that is sold in the separating equilibrium. The following proposition characterizes the optimal securities given M and A.

Proposition 3. *Assume that $f_L(\theta)/f_H(\theta)$ is decreasing in θ. The optimal security sold in the pooling equilibrium is a standard debt contract y_D such that*

$$y_D(\theta) = M + A\min(\theta, D),$$

and the optimal security sold in the separating equilibrium is the residual (equity) tranche $y_E(\theta) = A\max(0, \theta - D)$. The prices of the securities are given by

$$q_D = M + A\left[\underline{\theta} + \lambda \int_{\underline{\theta}}^{D} \widetilde{F}_L(\theta)d\theta + (1-\lambda)\int_{\underline{\theta}}^{D} \widetilde{F}_H(\theta)d\theta\right], \tag{10}$$

and

$$q_E = A\int_{D}^{\overline{\theta}} \widetilde{F}_L(\theta)d\theta. \tag{11}$$

Moreover, if $M \geq Am^*$, D is equal to $\overline{\theta}$ and the optimal security is pass-through. If $M < Am^*$, the debt threshold $D \in \left(\underline{\theta}, \overline{\theta}\right)$ is the unique solution to:

$$(z-1)\left[M/A + \left(\underline{\theta} + \lambda\int_{\underline{\theta}}^{D} \widetilde{F}_L(\theta)d\theta + (1-\lambda)\int_{\underline{\theta}}^{D} \widetilde{F}_H(\theta)d\theta\right)\right] = \lambda\int_{\underline{\theta}}^{D}\left[\widetilde{F}_H(\theta) - \widetilde{F}_L(\theta)\right]d\theta. \tag{12}$$

There are several notable features of optimal securities. The debt tranche promises the cash flow from the safe asset and each unit of the risky asset up to the debt threshold D. That is, the face value of debt is $M + AD$. When the cash flow from the risky asset is below D debt pays less than its face value; hence, it is risky.

Recall that when $E_L\theta/E_H\theta < \zeta$, a security backed by the cash flow of the risky asset is sold in the separating equilibrium. To create a security sold in a pooling equilibrium, agent B needs to either combine the risky asset with the safe asset or tranche the risky asset, or both. If $M \geq Am^*$, each unit of the risky asset is combined with enough safe assets to ensure that the participation constraint of the high type is not binding. In this case, there is no need to tranche the risky asset and the security (on the liability side of the balance sheet) backed by the entire cash flow from the portfolio of safe and risky assets (on the asset side of the balance sheet) is sold in the pooling equilibrium. When $M < Am^*$, the high type prefers not to trade a security that promises the entire combined cash flow. In this case, debt threshold D must be lowered so that the high type retains the equity tranche, which is the residual claim on the cash flow from the risky asset when the state exceeds D. The high type is then incentivized to participate in selling the debt tranche. Therefore, debt threshold D is determined by the incentive constraint of the high type, which is given by equation (12). By Proposition 1, the prices of the optimal debt and equity securities are given by (10) and (11).

5.2 Optimal Design of Liabilities

Using proposition 1, we can express agent B's benefit from holding m units of the safe asset and one unit of the risky asset as follows,

$$V(m,1) = \begin{cases} z\left[m + (\lambda E_L\theta + (1-\lambda)E_H\theta)\right] & \text{if } m \geq m^* \\ z\left[m + \left(\underline{\theta} + \lambda \int_{\underline{\theta}}^{\overline{\theta}} \widetilde{F}_L(\theta)d\theta + (1-\lambda)\int_{\underline{\theta}}^{D} \widetilde{F}_H(\theta)d\theta\right)\right] & \\ +(1-\lambda)\int_{D}^{\overline{\theta}} \widetilde{F}_H(\theta)d\theta & \text{if } m < m^* \end{cases}$$

where D solves:

$$(z-1)\left[m + \left(\underline{\theta} + \lambda \int_{\underline{\theta}}^{D} \widetilde{F}_L(\theta)d\theta + (1-\lambda)\int_{\underline{\theta}}^{D} \widetilde{F}_H(\theta)d\theta\right)\right] = \lambda \int_{\underline{\theta}}^{D}\left[\widetilde{F}_H(\theta) - \widetilde{F}_L(\theta)\right]d\theta. \tag{13}$$

Agent B's benefit from holding M units of the safe asset and A units of the risky asset is then $V(M,A) = AV(M/A,1)$.

Let $D(m)$ be the unique solution to (13) for $m \leq m^*$. The marginal benefit of holding m units of safe asset per unit of the risky collateral is

$$\frac{d}{dm}V(m,1) = \frac{\partial V}{\partial m} + \frac{\partial V}{\partial D}\frac{\partial D}{\partial m} = z + h\left(D\left(m\right)\right)$$

where

$$h\left(\theta\right) = \frac{(z-1)(1-\lambda)\tilde{F}_H(\theta)}{\frac{\lambda z}{z-1}\left[\tilde{F}_H(\theta) - \tilde{F}_L(\theta)\right] - \tilde{F}_H(\theta)}.$$

Holding marginally more safe asset per unit of risky collateral has a direct benefit and an indirect benefit. The direct benefit is that agent B can raise more capital to realize the gain from trade, z. The indirect benefit is that the debt threshold D is now higher. The value of the indirect benefit is $h(D(m))$. We characterize properties of h in Lemma 2 which shows that as the debt threshold increases, the indirect benefit falls.

The following proposition characterizes the optimal choice of safe assets per unit of risky collateral.

Proposition 4. *Let $\overline{p} = z + h(D(0))$ and $\widehat{p} = z + h\left(\overline{\theta}\right)$. Let $\widetilde{m}$ be the optimal amount of safe assets per unit of risky asset and $\widetilde{D}$ be the debt threshold. There are the following three cases.*

(i) If $\widehat{p} < p < \overline{p}$, $p = z + g\left(\widetilde{D}\right)$, and the debt threshold is $\widetilde{D} = D(\widetilde{m})$.

(ii) If $p < \widehat{p}$ then $\widetilde{m} = m^*$ and the debt threshold is $\widetilde{D} = \overline{\theta}$.

(iii) If $p > \overline{p}$ then $\widetilde{m} = 0$, and the debt threshold is $\widetilde{D} = D(0)$.

If the marginal cost of holding safe assets is low, it is optimal to combine each unit of risky collateral with m^* units of safe assets. In this case, the pass-through security is traded in a pooling equilibrium and there is no need to create the costly equity tranche. On the other hand, if the cost of holding safe assets is high, it is optimal to tranche risky collateral into a debt tranche and an equity tranche and use no safe assets. If the cost of holding safe assets is intermediate, it is optimal to combine the risky asset with the safe asset and create a larger debt tranche. The safe asset and the risky asset are again complements. Safe assets allow agent B to reduce the costly equity tranche and tranching allows agent B to use less costly safe assets. Figure 1 illustrates Proposition 4 and shows how to find the amount of safe assets per unit of risky collateral, $\widetilde{m}$, and the corresponding debt threshold $\widetilde{D}$ in case 1 of Proposition 4.

Given the optimal amount of safe assets per unit of risky asset $\widetilde{m}$ and the corresponding debt threshold $D(\widetilde{m})$, agent B's chooses the amount of the risky asset A to maximize $AV(\widetilde{m}, 1) - pA\widetilde{m} - p(A; r)$, which completes the characterization of the optimal balance sheet.

5.3 Public Safe Assets and Private Safe Debt: Substitutes or Complements?

Empirical studies have shown that the abundance of safe assets may crowd out private (short-term) safe debt creation. For example, Krishnamurthy and Vissing-Jorgensen (2015) show that the net private safe debt (i.e., private debt minus treasuries) decreases in the amount of treasuries. Thus far, we have highlighted the complementarity between safe assets and private debt creation. The channel is that safe assets lower the adverse selection in the economy, which allows for a larger private (safe) debt tranche and more borrowing. To starkly illustrate this channel, we have assumed that gains from trade feature constant returns to scale technology, i.e., marginal return z is constant.

When we allow gains from trade to be decreasing returns to scale, i.e., marginal return decreases as

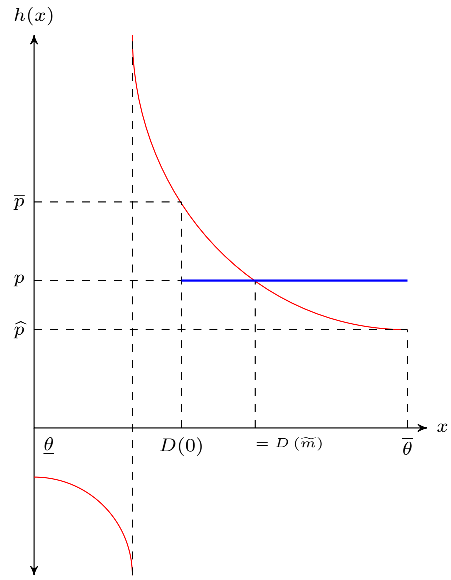

Figure 1: Construction of $\widetilde{m}$ and $\widetilde{D}$.

the amount of total borrowing increases, substitution between safe assets and private (safe) debt (i.e., crowding out of private debt) arises. To illustrate this possibility in a simple way, suppose there are many nonatomistic bankers indexed by $i \in [0,1]$. On the asset side of the balance sheet, each banker holds M units of the public safe asset and A units of the risky asset. Individual bankers take return per unit of investment $z > 1$ as given which is determined endogenously as we describe later. The quality of the risky asset is low with probability $\lambda \in (0,1)$ and high with probability $1-\lambda$, and the quality is drawn independently for each banker. After privately observing the asset quality, each banker chooses the security design and trades the securities in segmented over-the-counter markets. As in the main model, the optimal design involves a liquid debt with a threshold D_i, which is traded by both types and an illiquid residual equity tranche that is traded by only the low type.

Since all bankers are identical ex ante, they choose the same debt threshold $D = D_i$, and the amount they raise from the sale of securities depends only on their types. We denote the amount raised by type Q banks by x_Q. Total borrowing in the economy is $x = \lambda x_L + (1-\lambda)\, x_H$. Gains generated by x units of total borrowing by all bankers in the economy are given by $Z\,(x)$ where $Z'\,(x) > 0 > Z''\,(x)\,,\ Z'\,(0) > 1$. In equilibrium we have $Z\,(x) = z\,(x)\,x$. That is, the sum of the gains experienced by individual bankers is equal to the total gains in the economy. Importantly, economy-wide gains have decreasing returns to scale even though each banker perceives her own gain as constant returns to scale. In addition, since Z

is concave, individual bankers perceive higher gains from trade per unit of borrowing than the marginal gains from trade at the aggregate level. That is, $z(x) = Z(x)/x > Z'(x)$. In equilibrium, $z(x)$ must exceed 1; otherwise, bankers have an incentive to reduce borrowing. However, the marginal gain from borrowing at the aggregate level may be less than 1 in equilibrium.

Given the debt threshold D, the amount of borrowing by the high type banker is:

$$x_H = M + A\left(\underline{\theta} + \lambda \int_{\underline{\theta}}^{D} \widetilde{F}_L(\theta)d\theta + (1-\lambda)\int_{\underline{\theta}}^{D} \widetilde{F}_H(\theta)d\theta\right) \tag{14}$$

and the borrowing by the low type is:

$$x_L = x_H + A\int_{D}^{\overline{\theta}} \widetilde{F}_L(\theta)d\theta. \tag{15}$$

The incentive compatibility constraint (12) of the high type banker is:

$$(z(x) - 1)\, x_H = A\lambda \int_{\underline{\theta}}^{D} \left[\widetilde{F}_H(\theta) - \widetilde{F}_L(\theta)\right] d\theta. \tag{16}$$

Using (14)-(16) we obtain:

$$\frac{\partial D}{\partial M} = \frac{z(x) - 1 + z'(x)x_H}{A\left[\widetilde{F}_H(D) - (z(x) + z'(x)x_H)\left(\lambda\widetilde{F}_L(D) + (1-\lambda)\widetilde{F}_H(D)\right)\right]}. \tag{17}$$

Following similar arguments to those in the proof of Lemma 1, we can show that the denominator of (17) is positive. Hence, there is crowding out when $z(x) < 1 - z'(x)x_H$. Plugging in for $Z(x) = z(x)\,x$ and $Z'(x) = z(x) + z'(x)\,x$ we observe that crowding out occurs whenever $Z'(x)\frac{x_H}{x} + \frac{Z(x)}{x}\left(1 - \frac{x_H}{x}\right) < 1$.

This condition suggests that safe assets are likely to crowd out private debt creation when the aggregate investment is high (i.e., $Z'(x) < 1$) and the illiquid equity tranche is small (i.e., x_H is close to x, which occurs when adverse selection is mild, e.g., λ is low or $E_L\theta/E_H\theta$ is high).

6 Implications and Applications

In this section, we consider the implications of our model for monetary policies, in particular, the pricing of safe assets and QE operations.

6.1 Safety Premium and Liquidity Premium Decomposition

Krishnamurthy and Vissing-Jorgensen (2012) show that the convenience yield on treasury bonds has two components, liquidity premium and safety premium, approximately 46 basis points and 26 basis points per year, respectively, during the sample period 1926–2008. We show next that the balance sheet multiplier premium on a safe asset can be decomposed into these two components. In our model, safe assets are free from adverse selection but might have stochastic cash flows. In reality, the cash flows of safe assets might be volatile for a number of reasons. For example, treasury bonds of various maturities are exposed to different magnitudes of inflation risks. The convenience yields of safe assets might be time varying as well. To capture the aggregate risk embedded in the safe assets, we consider an endowment economy with many aggregate states $\omega \in \Omega$ as outlined in the section 2.1. Agents are endowed with M_ω units of the safe asset s_ω and A_ω units of risky asset r_ω for all $\omega \in \Omega$.

Consider a safe asset d that pays d_ω in state ω. Denote the liquidity value of an asset by p_d. The value of the asset d is

$$\begin{aligned} p_d &= E\left[d_\omega \frac{\partial V_\omega}{\partial M}(M_\omega, A_\omega)\right] \\ &= E\frac{\partial V_\omega}{\partial M}(M_\omega, A_\omega)Ed_\omega + Cov\left[d_\omega, \frac{\partial V_\omega}{\partial M}(M_\omega, A_\omega)\right] \end{aligned} \tag{18}$$

For p_d to be the market price of the asset, the bank must be the marginal investor. Denote the market price of an asset p_d^*. Barring short selling constraint, the market price of the asset is weakly greater than p_d, $p_d^* \geq p_d$, with equality only strict if bankers hold the asset in equilibrium. If the price of the asset is above p_d, then there is no demand from bankers. [15]

Thus far, we have not attached an economic meaning to the aggregate state ω. In an environment where the aggregate payoff of safe assets is volatile, the aggregate state ω can be interpreted as the aggregate safe asset payoff. Under this interpretation, because securities are contingent on the aggregate state, when ω is higher, there is a positive shift in the supply of safe assets that affects the security design. In particular, when ω is higher, the face value of the debt tranche increases, and the marginal value of the safe asset payoff in that state goes down.

A shift in the aggregate state may also shift the payoff distribution of the risky asset, but, for simplicity, suppose that the payoff of the risky asset is independent of state ω, $F_Q(\theta;\omega) = F_Q(\theta)$ and that the total supply of risky assets equals 1. Denote $v(\omega) = V_\omega(\omega, 1)$ for all ω. The price of the safe asset d is then

$$\begin{aligned} p(d) &= E\left[d(\omega)v'(\omega)\right] \\ &= Ev'(\omega)Ed(\omega) + Cov\left[d(\omega), v'(\omega)\right] \end{aligned} \tag{19}$$

[15] We ignore the regulatory requirement for banks to hold safe assets, since recent empirical evidence has shown that banks hold more safe assets than what the regulation demands.

We observe from (19) that if $Cov\left[d(\omega), v'(\omega)\right] < 0$ then there exists a risk premium on asset d:

$$p(d) < p(E(d)).$$

This result mirrors the standard result from asset pricing: any asset whose payoff covaries negatively with the marginal utility of consumption is priced below a safe asset with the same expected payoff. As an example, consider a safe asset d whose payoff is increasing in the aggregate state ω. For such an asset, we have $Cov\left[d(\omega), v'(\omega)\right] < 0$ and there is a risk premium.[16]

In general, safe assets with volatile cash flows still have the balance sheet multiplier effect in some realization of the world. This means that its equilibrium value is above its autarky value,

$$E(d) < p(d).$$

The liquidity premium of the safe asset d, with expected payment $E(d)$ is

$$\text{liquidity premium } \equiv \frac{p(d) - E(d)}{E(d)} = Ev'(\omega) - 1 + Cov \left. \frac{d(\omega)}{E(d)}, v'(\omega)\right]. \tag{20}$$

The safety premium for the safe asset that pays $E(d)$ deterministically for all ω over the safe asset d is

$$\text{safety premium} \equiv \frac{p(E(d)) - p(d)}{E(d)} = -Cov \left. \frac{d(\omega)}{E(d)}, v'(\omega)\right]. \tag{21}$$

This decomposition generates both business cycle and cross-sectional implications of safe asset pricing. Our model would predict that the liquidity premium component is relatively larger during the boom when gains from trade are greater and the opposite is true for safety premiums. Cross-sectionally, shorter maturity treasuries (and inflation protected treasuries) feature larger safety premiums than longer maturity treasuries.[17]

In reality, there are many types of assets that are free from adverse selection, such as broad market indices (e.g., SP500). Our theory sheds light on why these assets are not commonly used as collateral multipliers on banks' balance sheets. Unlike the treasury securities, the covariance term in (21) for broad market indices is negative (that is, they are positively exposed to aggregate market risk). Consequently, these adverse-selection free assets have a too high risk premium for the banks to use them as liquidity multipliers (i.e., their market price exceeds their value given in (18)).

[16]To see why, recall that $v''(M_\omega) < 0$ for M_ω below a certain level. Let $\overline{d}(M_\omega) = d(\omega)$. The function $\overline{d}$ is well-defined and increasing because d is increasing in M_ω. Now note that $Cov\left[d(\omega), v'(M_\omega)\right] = Cov\left[\overline{d}(M_\omega), v'(M_\omega)\right] < 0$. The inequality follows because $\overline{d}$ is increasing and v' is decreasing in M_ω.

[17]Relatedly, Geromichalos, Herrenbrueck, and Lee (2018) differentiates asset safety from asset liquidity in an environment with search frictions. Holmström and Tirole (2001) provides a theory of the value of liquidity and safety in an environment with limited commitment.

6.2 Quantitative Easing as Balance Sheet Design of the Government

In this section, based on the main setup of our model, we formulate unconventional monetary policy as an optimal balance sheet design problem for the government with a limited fiscal capacity. We consider an environment where the banking sector has an endowment of M units of the safe asset s and A units of the risky asset r. The government maximizes the total value of the banking sector by removing risky assets from and/or injecting safe assets into their balance sheets. These actions are potentially costly to the government because they affect the composition and the size of the government's own balance sheet. The cost to the government of a given policy depends on its fiscal capacity. However, compared with the private banking sector, the government has an advantage in creating safe assets due to its commitment power.

Specifically, we assume that the QE program is implemented uniformly to all banks so that risky assets that the government exchanges for safe assets are of average quality, i.e., low quality with probability λ and high quality with probability $1-\lambda$. The government backs the safe payment at date 2 through taxation and the cash flow payoff from the risky assets that it obtains in exchange for the safe assets that it provides to agent B. Suppose transferring τ extra units of safe payment to the banking sector's balance sheet at date 2 costs $c_\tau(\tau)$. We assume that (i) taxation is costly: $c_\tau(\tau) \geq \tau$; (ii) no taxation has zero cost: $c_\tau(0) = 0$; (iii) the cost function is smooth: $c'_\tau(0) = 1$; and (iv) the cost of taxation is convex: $c''_\tau \geq 0$ with a strict inequality for $\tau > 0$.[18] Let E_θ denote the expectations over θ taken with respect to the average quality distribution $\lambda F_L + (1-\lambda) F_H$. Now, we can express the government's optimization problem as follows:

$$\max_{\{\tau_\theta, \tilde{M}, \tilde{A}\}} V(\tilde{M}, \tilde{A}) - E_\theta \left[c_\tau(\tau_\theta)\right]$$

subject to

$$\tilde{M} - M + \theta(\tilde{A} - A) = \tau_\theta, \text{ for all } \theta \tag{22}$$

$$V(\tilde{M}, \tilde{A}) - E_\theta c_\tau(\tau_\theta) \geq V(M, A). \tag{23}$$

where τ_θ denotes government taxes in state θ, $\tilde{A}$ and $\tilde{M}$ denote the amounts of risky asset r and safe asset s that the private sector holds after QE transactions. Equation (22) is the government budget

[18] In general, if QE ends up with a surplus, i.e., if $\tau < 0$, the government would lower its overall tax bill. This formulation also allows for the possibility that the government simply transfers the surplus from its intervention to the banks, in which case $c_\tau(\tau) = \tau$ if $\tau < 0$.

constraint in implementing QE. The operator E_θ captures the commitment power of the government, that is, the government does not cherry pick assets of good quality. Equation (23) is the private banks' participation constraint in the QE program.

The government budget constraint (22) depends on the tax revenue of the government at that state and the amount of quality sensitive assets that the government purchases from the private sector. Because agents are risk neutral in this economy, the safe asset payment holds in expectation, and is invariant across realized payment from quality-sensitive assets.

The government optimization problem implies that

$$E_\theta\left[c_\tau'(\tau_\theta)\right] = \frac{\partial}{\partial M} V\left(\tilde{M}, \tilde{A}\right) \tag{24}$$

$$E_\theta\left[\theta c_\tau'(\tau_\theta)\right] = \frac{\partial}{\partial A} V\left(\tilde{M}, \tilde{A}\right) \tag{25}$$

Equations (24) and (25) tie the private value of safe assets and risky assets, or their market price, to the fiscal cost for the government to create safe assets and to hold risky assets through QE. The left side of (24) is the taxation costs of delivering a unit in all states θ. This is the fiscal cost of creating a unit of safe assets. The left side of (25) is the taxation costs of delivering θ payment in state θ. This is the fiscal benefit of holding a unit of the risky asset to the government. The right side of Equation (24) and (25) is the private values of safe and risky assets, or equivalently, their market prices.

Note that if the government purchases risky assets through QE, $\tilde{A} < A$, τ_θ is decreasing in θ, and the marginal cost of taxation, $c_\tau'(\tau_\theta)$, negatively covariates with θ.

$$E_\theta\left[\theta c_\tau'(\tau_\theta)\right] = E_\theta\left[\theta\right] E_\theta\left[c_\tau'(\tau_\theta)\right] + Cov\left[\theta, c_\tau'(\tau_\theta)\right] < 0 \tag{26}$$

If 1 unit of a risky asset generates $E[\theta]$ unit of cash flow in every θ state, then the government does not need to use any taxation and QE is neutral. However, more taxes are needed for lower θ states, and the government has to fund QE in these states via distortionary taxes. Therefore, QE creates more fiscal risk to the government. In fact, the risk premium of the risky asset in an equilibrium with QE reflects the fiscal risk. Formally, define the credit spread between safe assets and risky assets (normalized by expected payment) as,

$$S = \frac{\partial}{\partial M} V\left(\tilde{M}, \tilde{A}\right) - \left[E_\theta \theta\right]^{-1} \frac{\partial}{\partial A} V\left(\tilde{M}, \tilde{A}\right) \tag{27}$$

It reflects the fiscal capacity and the cost of taxation of the government: the higher the spread, the lower the fiscal capability of a country to conduct QE. This generates interesting testable implications across countries and their aggregate asset risk premiums.

7 Conclusion

In this paper we find that safe assets have a role in coordinating equilibrium beliefs and help to expand borrowers' balance sheet in the economy. They have a multiplier effect on risky collateral production in the economy. We also find that there are complementarities between safe asset holdings and the leverage of borrowers when adverse selection is severe in the economy, while the substitution between safe assets and private safe debts arise when there are plenty of safe assets and gain from trade between borrowers and investors is decreasing in the amount of safe assets in the economy. The model can be used to understand the endogenous capital structure/balance sheet of the banks as producers of pledgeable securities, safety and liquidity premiums of safe assets, and the implication of various monetary policies such as QE.

A Proofs

A.1 Proof of Proposition 1

If $r_\omega > \zeta \equiv 1-(z-1)/\lambda z$, in the market for security y the price of the security is $q(\omega) = \lambda E_L^\omega y(\omega,\theta) + (1-\lambda) E_H^\omega y(\omega,\theta)$ and $a_L(\omega) = a_H(\omega) = 1$. If $r_\omega < \zeta$ the price of the security is $q(\omega) = E_L^\omega y(\omega,\theta)$ and $a_L(\omega) = 1$ and $a_H(\omega) = 0$.

Let $q_P(\omega) \equiv \lambda E_L^\omega y(\omega,\theta) + (1-\lambda) E_H^\omega y(\omega,\theta)$. Note that $zq_P(\omega) - E_H^\omega y \gtreqless 0$ iff $E_L^\omega y(\omega,\theta)/E_H^\omega y(\omega,\theta) \gtreqless \zeta$.

Consider the case $E_L^\omega y(\omega,\theta)/E_H^\omega y(\omega,\theta) > \zeta$. Suppose that the equilibrium price $q(\omega)$ is strictly less than $q_P(\omega)$. In this case an investor can deviate and bid $q_P(\omega)-\epsilon$ where $\epsilon > 0$. For ϵ small enough, $z(q_P(\omega)-\epsilon) - E_H^\omega y(\omega,\theta) > 0$. Hence at this price both types sell the security and the deviation generates strictly positive surplus. This means that the equilibrium price must be at least $q_P(\omega)$. At price above $q_P(\omega)$ investors make negative profit, so in equilibrium $q(\omega) = q_P(\omega)$.

Now consider the case $E_L^\omega y(\omega,\theta)/E_H^\omega y(\omega,\theta) < \zeta$. In this case high type will sell the security only if $q(\omega)$ is sufficiently larger than $q_P(\omega)$. However, at prices above $q_P(\omega)$, investors make negative profit. Hence equilibrium price must be below $q_P(\omega)$. If $q(\omega)$ is below $E_L^\omega y(\omega,\theta)/z$ then neither type sells the security. In this case, one of the investors can deviate and bid $E_L^\omega y(\omega,\theta) - \delta$ where $\delta > 0$. For δ small enough, $z(E_L y - \delta) - E_L y > 0$ so the low type sells the security and the deviating agent makes strictly positive surplus. If $q(\omega)$ is at least $E_L^\omega y(\omega,\theta)/z$ but less than $E_L^\omega y(\omega,\theta)$ then the low type sells the security to the investors who bid that price. In this case, one of the investors who bids $E_L^\omega y(\omega,\theta)$

or less can deviate and bid slightly above $q(\omega)$. This agent then buys the security alone and increases her surplus. At prices greater than equal to $E_L^{\omega} y(\omega, \theta)$ (and below $q_P(\omega)$), the low type alone sells the security. Hence the only price that is consistent with zero profit condition is $q(\omega) = E_L^{\omega} y(\omega, \theta)$.

A.2 Proof of Proposition 3

The security designer's problem can be written as:

$$\max_{y(\theta)} E_H y(\theta) \tag{28}$$

$$s.t. M + A\theta - y(\theta) \geq 0, \forall \theta,$$

$$E_L y(\theta) - \zeta E_H y(\theta) \geq 0,$$

$$y(\theta) \text{ is weakly increasing on } [\underline{\theta}, \overline{\theta}]. \tag{29}$$

The first constraint above is the feasibility constraint and requires $y(\theta)$ to be backed by the underlying asset in every state. The second is the pooling constraint and guarantees that the high type agent sells the liquid security y.

Let's write the monotone security $y(\theta)$ as:

$$y(\theta) = M + A\underline{\theta} + \int_{\underline{\theta}}^{\theta} x(j)dj,$$

where $x(j) \geq 0$ for all $j \in [\underline{\theta}, \overline{\theta}]$.[19] Let $\widetilde{F}_Q(\theta) = 1 - F_Q(\theta)$ for $Q \in \{L, H\}$ and $\theta \in [\underline{\theta}, \overline{\theta}]$. Then,

$$E_Q y(\theta) = M + A\underline{\theta} + \int_{\underline{\theta}}^{\overline{\theta}} \widetilde{F}_Q(j) x(j) dj.$$

Hence, the optimal security design problem (**??**) is equivalent to the following problem:

$$\arg\max_{x} \int_{\underline{\theta}}^{\overline{\theta}} \widetilde{F}_H(s) x(s) ds, \tag{30}$$

$$s.t. \int_{\underline{\theta}}^{\theta} x(j)dj \leq \theta - \underline{\theta}, \forall \theta \in [\underline{\theta}, \overline{\theta}], \tag{31}$$

$$\int_{\underline{\theta}}^{\overline{\theta}} \left[\widetilde{F}_L(\theta) - \zeta \widetilde{F}_H(\theta)\right] x(\theta) d\theta + (1 - \zeta)\left[A\underline{\theta} + M\right] \geq 0, \tag{32}$$

$$x(\theta) \geq 0, \forall \theta \in [\underline{\theta}, \overline{\theta}] \tag{33}$$

[19] In our analysis, we restrict attention to securities that can be written as the sum of an absolutely continuous increasing function and countably many jump points.

In the above problem, (31) corresponds to the feasibility constraint, (32) corresponds to the pooling constraint and (33) guarantees that the security is monotone.

First note that the feasible set is compact, convex and nonempty so the optimization problem must have a solution. Moreover, since the objective function is bounded above, the solution must be finite. The Lagrangian of the optimization problem is

$$\begin{aligned}\mathcal{L}(x;\gamma,\mu,\mu_x) = &\int_{\underline{\theta}}^{\overline{\theta}} \widetilde{F}_H(\theta)x(\theta)d\theta + \int_{\underline{\theta}}^{\overline{\theta}} \gamma(\theta)\left[\theta-\underline{\theta}-\int_{\underline{\theta}}^{\theta} x(j)dj\right]d\theta \\ &+\mu\left\{\int_{\underline{\theta}}^{\overline{\theta}}\left[\widetilde{F}_L(\theta)-\zeta\widetilde{F}_H(\theta)\right]x(\theta)d\theta+(1-\zeta)\left[A\underline{\theta}+M\right]\right\}+\int_{\underline{\theta}}^{\overline{\theta}}\mu_x(\theta)x(\theta)d\theta.\end{aligned}$$

Note that for any feasible x and for $\gamma \geq 0$, $\mu \geq 0$ and $\mu_x \geq 0$ we have

$$\mathcal{L}(x;\gamma,\mu,\mu_x) \geq \int_{\underline{\theta}}^{\overline{\theta}} \widetilde{F}_H(\theta)x(\theta)d\theta.$$

Let $\mathcal{L}(\gamma,\mu,\mu_x) = \max_x \mathcal{L}(x;\gamma,\mu,\mu_x)$. Let $\mathcal{L}^* = \min_{\gamma\geq 0,\mu\geq 0,\mu_x\geq 0}\mathcal{L}(\gamma,\mu,\mu_x)$. Note that $\mathcal{L}^*$ is the value of the original optimization problem. Letting $\eta(\theta) = \int_{\theta}^{\overline{\theta}}\gamma(j)dj$, we can rewrite the Lagrangian as:

$$\begin{aligned}\mathcal{L}(x;\eta,\mu,\mu_x) = \; &\textstyle\int_{\underline{\theta}}^{\overline{\theta}}\left\{\widetilde{F}_H(\theta)+\mu\left[\widetilde{F}_L(\theta)-\zeta\widetilde{F}_H(\theta)\right]-\eta(\theta)+\mu_x(\theta)\right\}x(\theta)d\theta \\ &+\mu(1-\zeta)\left[A\underline{\theta}+M\right]+\textstyle\int_{\underline{\theta}}^{\overline{\theta}}\eta(\theta)\,d\theta.\end{aligned}$$

Now note that the quantity inside the curly brackets must be zero or otherwise the value of the optimization problem would be infinite. Let $H_\mu(\theta) = \widetilde{F}_H(\theta)+\mu\left[\widetilde{F}_L(\theta)-\zeta\widetilde{F}_H(\theta)\right]$. Consider the following problem:

$$\begin{aligned}\min_{\mu\geq 0}\quad \min\nolimits_{\eta\geq 0}\quad &\mu(1-\zeta)\left[A\underline{\theta}+M\right]+\int_{\underline{\theta}}^{\overline{\theta}}\eta(\theta)\,d\theta \\ s.t.\quad &\eta(\theta)\geq H_\mu(\theta),\end{aligned}$$

and the constraint that $\eta(\theta)$ is a decreasing function in θ. The value of this problem is $\mathcal{L}^*$. Note, $h_\mu(\theta) \equiv \frac{\partial H_\mu(\theta)}{\partial\theta} = -f_H(\theta)\left[1+\mu\left(\frac{f_L(\theta)}{f_H(\theta)}-\zeta\right)\right]$. Clearly $H_\mu(\underline{\theta}) > 0$ and $H_\mu\left(\overline{\theta}\right) = 0$. Since $\mu > 0$ we must have $h_\mu(\underline{\theta}) < 0$. To see this suppose $h_\mu(\underline{\theta}) \geq 0$. Then it must be the case that $1+\mu\left(\frac{f_L(\underline{\theta})}{f_H(\underline{\theta})}-\zeta\right) \leq 0$. Since $\frac{f_L(\theta)}{f_H(\theta)}$ is decreasing, this implies that $h_\mu(\theta) > 0$ for all $\theta \in (\underline{\theta},\overline{\theta}]$ contradicting that $H_\mu\left(\overline{\theta}\right) = 0$.

Since $\frac{f_L(\theta)}{f_H(\theta)}$ is decreasing in θ one of the following must be true:

(i) There exists a unique cutoff $\widehat{\theta}_\mu \in (\underline{\theta},\overline{\theta})$ such that $h_\mu(\theta) < 0$ for $s < \widehat{\theta}_\mu$ and $h_\mu(\theta) > 0$ for $\theta > \widehat{\theta}_\mu$,

(ii) $h_\mu(\theta) < 0$ for all $\theta \in (\underline{\theta},\overline{\theta})$.

In case (i) the function $H_\mu(\theta)$ crosses from positive to negative once, eventually increasing to zero at $\overline{\theta}$. In case (ii) $H_\mu(\theta)$ decreases to zero at $\overline{\theta}$. Let $\theta^*_\mu \in (\underline{\theta},\overline{\theta})$ be the unique θ for which $H_\mu(\theta) = 0$ if it exists, otherwise let $\theta^*_\mu = \overline{\theta}$.

Note that for given $\mu \geq 0$ optimal η_μ is given by:

$$\eta_\mu(\theta) = \begin{cases} H_\mu(\theta) & \text{if} \quad \theta \leq \theta_\mu^* \\ 0 & \text{if} \quad \theta > \theta_\mu^* \end{cases}.$$

Plugging this into the minimization problem we get:

$$\min_{\mu \geq 0} \mu(1-\zeta)\left[A\underline{\theta} + M\right] + \int_{\underline{\theta}}^{\theta_\mu^*} \quad \widetilde{F}_H(\theta) + \mu\left[\widetilde{F}_L(\theta) - \zeta\widetilde{F}_H(\theta)\right]\Big)\, d\theta.$$

The first order condition for this problem is:

$$(1-\zeta)\left[A\underline{\theta} + M\right] + \int_{\underline{\theta}}^{\theta_\mu^*} \left[\widetilde{F}_L(\theta) - \zeta\widetilde{F}_H(\theta)\right] d\theta + \frac{\partial\theta_\mu^*}{\partial\mu} H_\mu\left(\theta_\mu^* \right. \geq 0$$

Because $H_\mu\left(\theta_\mu^* \right. = 0$,

$$(1-\zeta)\left[A\underline{\theta} + M\right] + \int_{\underline{\theta}}^{\theta_\mu^*} \left[\widetilde{F}_L(\theta) - \zeta\widetilde{F}_H(\theta)\right] d\theta \geq 0$$

with complementary slackness.

Let $\theta^* \in \left(\underline{\theta}, \overline{\theta}\right]$ be the unique θ for which

$$(1-\zeta)\left[A\underline{\theta} + M\right] + \int_{\underline{\theta}}^{\theta^*} \left[\widetilde{F}_L(\theta) - \zeta\widetilde{F}_H(\theta)\right] d\theta = 0$$

if it exists, and let $\theta^* = \overline{\theta}$ otherwise.

If $\theta^* < \overline{\theta}$ then $\mu > 0$, $\theta_\mu^* = \theta^*$, and

$$\mathcal{L}^* = \mu(1-\zeta)\left[A\underline{\theta} + M\right] + \int_{\underline{\theta}}^{\theta^*} \quad \widetilde{F}_H(\theta) + \mu\left[\widetilde{F}_L(\theta) - \zeta\widetilde{F}_H(\theta)\right] \quad d\theta = \int_{\underline{\theta}}^{\theta^*} \widetilde{F}_H(\theta) d\theta.$$

If $\theta^* = \overline{\theta}$ then $\mu = 0$, $\theta_\mu^* = \overline{\theta}$, and

$$\mathcal{L}^* = \int_{\underline{\theta}}^{\overline{\theta}} \widetilde{F}_H(\theta) d\theta.$$

To complete the proof, let $D = \theta^*$ and note that $x(\theta) = 1$ for $\theta \in [\underline{\theta}, D)$ and $x(\theta) = 0$ for $\theta \in \left[D, \overline{\theta}\right]$ achieves the value $\mathcal{L}^*$ and it is feasible, and must be optimal for the original problem. This completes the proof that the optimal security sold in the pooling equilibrium is a standard debt contract y_D such that

$$y_D(\theta) = M + A\min(\theta, D),$$

and the optimal security sold in the separating equilibrium is the residual (equity) tranche $y_E(\theta) = A\max(0, \theta - D)$. It follows immediately that if $M \geq Am^*$, D is equal to $\overline{\theta}$ and the optimal security is pass-through. If $M < Am^*$, the debt threshold $D \in \left(\underline{\theta}, \overline{\theta}\right)$ is the unique solution to the high type's IC constraint given by (13). The following lemma completes the proof.

Lemma 1. *If $M/A \leq m^*$, there exists a unique $D \in \left(\underline{\theta}, \overline{\theta}\right)$ that solves (13) which is strictly increasing in M.*

Proof. Let $m = M/A$ and

$$\Upsilon(x) = \lambda \int_{\underline{\theta}}^{x} \left[\widetilde{F}_H(\theta) - \widetilde{F}_L(\theta)\right] d\theta - (z-1)\left[m + \left(\underline{\theta} + \lambda \int_{\underline{\theta}}^{x} \widetilde{F}_L(\theta) d\theta + (1-\lambda) \int_{\underline{\theta}}^{x} \widetilde{F}_H(\theta) d\theta\right)\right].$$

It is easy to check that $\Upsilon(\underline{\theta}) \leq 0$, $\Upsilon\left(\overline{\theta}\right) > 0$ if $m \leq m^*$. Hence, $\Upsilon(y) = 0$ at some $y \in \left(\underline{\theta}, \overline{\theta}\right)$. Denote the smallest such y by D. At D, Υ intersects the horizontal axis from below so $\Upsilon'(D) > 0$. Taking the derivative:

$$\Upsilon'(x) = \lambda z \left(\widetilde{F}_H(x) - \widetilde{F}_L(x)\right) - (z-1)\widetilde{F}_H(x).$$

Note $\Upsilon'(\underline{\theta}) < 0$, $\Upsilon'\left(\overline{\theta}\right) = 0$, and the second derivative is:

$$\Upsilon''(x) = \lambda z f_H(x) \quad \frac{f_L(x)}{f_H(x)} - \zeta \Bigg).$$

Since $f_L(\theta)/f_H(\theta)$ is decreasing in θ, Υ' is either decreasing for all θ or it is increasing and then (possibly) decreasing. Since $\Upsilon(\underline{\theta}) \leq 0$ and $\Upsilon'(\underline{\theta}) < 0$, if Υ' is decreasing everywhere then Υ cannot cross zero. Hence, it must be that Υ' is initially increasing, crosses zero and becomes positive and then decreases so that $\Upsilon'\left(\overline{\theta}\right) = 0$. If Υ crosses zero a second time at $\widetilde{D} < \overline{\theta}$, it must remain below zero at all $\theta > \widetilde{D}$, contradicting that $\Upsilon\left(\overline{\theta}\right) > 0$.

Finally, if m goes up, Υ shifts down and the point where it crosses zero shifts to the right, i.e., D increases. □

Lemma 2. *Define $h : \left[\underline{\theta}, \overline{\theta}\right] \to \mathbb{R}$ as:*

$$h(x) = \frac{(z-1)(1-\lambda)\tilde{F}_H(x)}{\frac{\lambda z}{z-1}\left[\tilde{F}_H(x) - \tilde{F}_L(x)\right] - \tilde{F}_H(x)}.$$

The function h is continuous and strictly decreasing everywhere, except at a single point $\widehat{D} \in \left(\underline{\theta}, \overline{\theta}\right)$ where it jumps from $-\infty$ to ∞, and this jump always occurs strictly below $D(0)$. In addition, $h(x) < 0$ for all $x < \widehat{D}$, $h(x) > 0$ for all $x \in \left(\widehat{D}, \overline{\theta}\right)$, and $h\left(\overline{\theta}\right) \geq 0$.

Proof. The denominator of h is $(z-1)^{-1}\Upsilon'(x)$ where Υ' is as defined in the proof of 1. We know that $\Upsilon'(\underline{\theta}) < 0$ and $\Upsilon'\left(\overline{\theta}\right) = 0$. We know from the proof of 1 that Υ' is initially increasing, crosses zero and becomes positive and then decreases to $\Upsilon'\left(\overline{\theta}\right) = 0$. Denote the point at which Υ' is zero by $\widehat{D}$. Taking the derivative of h we find that

$$h'(x) = \frac{(z-1)(1-\lambda)\frac{\lambda z}{z-1}\tilde{F}_L(x)\tilde{F}_H(x)}{\frac{\lambda z}{z-1}\left[\tilde{F}_H(x) - \tilde{F}_L(x)\right] - \tilde{F}_H(x)\Big)^2} \quad \frac{f_H(x)}{\tilde{F}_H(x)} - \frac{f_L(x)}{\tilde{F}_L(x)}$$

Recall that $f_L(x)/f_H(x)$ is decreasing in x implying that $F_H(\cdot)$ dominates $F_L(\cdot)$ in hazard rate so the term in parentheses is negative for all x, and h is decreasing. Note also that the numerator is positive for all x so $h(x) < 0$ for all $x < \widehat{D}$ and $h(x) > 0$ for all $x \in \left(\widehat{D}, \overline{\theta}\right)$. □

A.3 Proof of Proposition 4

Proof. Suppose agent B holds A units of risky collateral. The marginal benefit of holding m units of safe asset per unit of the risky collateral is $A[z + h(D(m))]$. By Lemma 2, for $D \geq D(0)$, marginal benefit is continuous and decreasing in D. In addition, $D(m)$ is continuous and increasing in m, so marginal benefit is continuous and decreasing in m. Marginal cost of m is pA. Hence if $p \geq z + h(D(0))$, marginal cost of m exceeds its marginal benefit for all $m > 0$ and $\widetilde{m} = 0$. If $p < z + h(D(0))$ and $p > z + h(\overline{\theta})$, there exists $\widetilde{m} \in (0, m^*)$ such that $p = z + g(D(\widetilde{m}))$. In this case, the optimal amount of safe asset per unit of risky asset is $\widetilde{m}$ and the corresponding debt threshold is $D(\widetilde{m}) \in \left(D(0), \overline{\theta}\right)$. If $p < z + h(\overline{\theta})$, the optimal amount of safe asset per unit of risky asset is $\widetilde{m} = m^*$ and the debt threshold is $\overline{\theta}$. □

References

Acharya, V. V., D. Gale, and T. Yorulmazer (2011). "Rollover risk and market freezes". *The Journal of Finance* 66.4, pp. 1177–1209.

Adrian, T. and H. S. Shin (2010). "Liquidity and leverage". *Journal of financial intermediation* 19.3, pp. 418–437.

— (2014). "Procyclical Leverage and Value-at-Risk". *Review of Financial Studies* 27.2, pp. 373–403.

Adrian, T. et al. (2013). "Repo and securities lending". In: *Risk Topography: Systemic Risk and Macro Modeling*. University of Chicago Press.

Akerlof, G. A. (1970). "The Market for" Lemons": Quality Uncertainty and the Market Mechanism". *The Quarterly Journal of Economics* 84.3, pp. 488–500.

Allen, F. and D. Gale (1988). "Optimal security design". *Review of Financial Studies* 1.3, pp. 229–263.

Andolfatto, D. and A. Spewak (2018). "On the Supply of, and Demand for, U.S. Treasury Debt". *Economic Synopses* 5.

Asriyan, V., W. Fuchs, and B. Green (2017). "Liquidity Sentiments". *Working paper.*

Asriyan, V. et al. (2019). *Monetary Policy for a Bubbly World*. Tech. rep. UPF.

Baklanova, V. et al. (2017). *The Use of Collateral in Bilateral Repurchase and Securities Lending Agreements*. Tech. rep. New York Federal Reserve.

Bernanke, B. S. and A. S. Blinder (1988). "Credit, Money, and Aggregate Demand". *American Economic Review* 78.2, pp. 435–439. URL: https://ideas.repec.org/a/aea/aecrev/v78y1988i2p435-39.html.

Bernanke, B. S. and V. R. Reinhart (2004). "Conducting Monetary Policy at Very Low Short-Term Interest Rates". *American Economic Review* 94.2, pp. 85–90. DOI: 10.1257/0002828041302118. URL: https://www.aeaweb.org/articles?id=10.1257/0002828041302118.

Biais, B. et al. (Apr. 2007). "Dynamic security design: convergence to continuous time and asset pricing implications". *Review of Economic Studies* 74.2, pp. 345–390. ISSN: 0034-6527. DOI: 10.1111/j.1467-937X.2007.00425.x. eprint: http://oup.prod.sis.lan/restud/article-pdf/74/2/345/18341422/74-2-345.pdf. URL: https://doi.org/10.1111/j.1467-937X.2007.00425.x.

Bigio, S. (2015). "Endogenous liquidity and the business cycle". *American Economic Review* 105.6, pp. 1883–1927.

Bigio, S. and P.-O. Weill (2016). *A Theory of Bank Balance Sheets*. Tech. rep. UCLA.

Boot, A. W. A. and A. V. Thakor (1993). "Security Design". *The Journal of Finance* 48.4, pp. 1349–1378.

Brunnermeier, M. K. and V. Haddad (In Preparation). "Safe Assets".

Brunnermeier, M. K. and L. H. Pedersen (2009). "Market liquidity and funding liquidity". *Review of Financial studies* 22.6, pp. 2201–2238.

Caballero, R. and E. Farhi (Feb. 2017). "The Safety Trap". *The Review of Economic Studies* 85.1, pp. 223–274. ISSN: 0034-6527. DOI: 10.1093/restud/rdx013. eprint: https://academic.oup.com/restud/article-pdf/85/1/223/23033558/rdx013.pdf. URL: https://doi.org/10.1093/restud/rdx013.

Caballero, R. J., E. Farhi, and P.-O. Gourinchas (2017). "The Safe Assets Shortage Conundrum". *Journal of Economic Perspectives* 31.3, pp. 29–46. DOI: 10.1257/jep.31.3.29. URL: https://www.aeaweb.org/articles?id=10.1257/jep.31.3.29.

Carlson, M. et al. (2016). "The Demand for Short-Term, Safe Assets and Financial Stability: Some Evidence and Implications for Central Bank Policies". *International Journal of Central Banking* 12.4, pp. 307–333.

CGFS (2017). *Repo Market Functioning*. Tech. rep. Committee on the Global Financial System, Bank of International Settlement.

Chemla, G. and C. A. Hennessy (2014). "Skin in the game and moral hazard". *Journal of Finance* 69.4, pp. 1597–1641. DOI: 10.1111/jofi.12161. eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1111/jofi.12161. URL: https://onlinelibrary.wiley.com/doi/abs/10.1111/jofi.12161.

Chiu, J. and T. V. Koeppl (2016). “Trading dynamics with adverse selection and search: Market freeze, intervention and recovery”. *The Review of Economic Studies* 83.3, pp. 969–1000.

Copeland, A., A. Martin, and M. Walker (2010). *The tri-party repo market before the 2010 reforms*. Tech. rep. Staff Report, Federal Reserve Bank of New York.

Dang, T. V., G. Gorton, and B. Holmström (2011). “Haircuts and Repo Chains”. *Manuscript. Columbia University.*

— (2013). “The information sensitivity of a security”. *Working paper.*

DeMarzo, P. M. (2005). “The Pooling and Tranching of Securities: A Model of Informed Intermediation”. *The Review of Financial Studies* 18.1, p. 1. DOI: `10.1093/rfs/hhi008`.

DeMarzo, P. M. and D. Duffie (1995). “Corporate incentives for hedging and hedge accounting”. *The review of financial studies* 8.3, pp. 743–771.

— (1999). “A liquidity-based model of security design”. *Econometrica* 67.1, pp. 65–99.

Denbee, E. et al. (2014). “Network risk and key players: a structural analysis of interbank liquidity”. *Working paper.*

Diamond, D. W. and P. H. Dybvig (1983). “Bank Runs, Deposit Insurance, and Liquidity”. *Journal of Political Economy* 91.3, pp. 401–419. DOI: `10.1086/261155`. eprint: `https://doi.org/10.1086/261155`. URL: `https://doi.org/10.1086/261155`.

Diamond, W. (2017). *Safety Transformation and the Structure of the Financial System*. Tech. rep. Stanford University.

Doepke, M. and M. Schneider (2017). “Money as a Unit of Account”. *Econometrica* 85.5, pp. 1537–1574. DOI: `https://doi.org/10.3982/ECTA11963`. eprint: `https://onlinelibrary.wiley.com/doi/pdf/10.3982/ECTA11963`. URL: `https://onlinelibrary.wiley.com/doi/abs/10.3982/ECTA11963`.

Donaldson, J. R., G. Piacentino, and A. Thakor (2018). “Warehouse banking”. *Journal of Financial Economics* 129.1, pp. 250–267.

Donaldson, J. R. and G. Piacentino (2017). “Money runs”. *Working papper, Washington University in St. Louis.*

Duffie, D. (1996). “Special repo rates”. *The Journal of Finance* 51.2, pp. 493–526.

Ellis, A., M. Piccione, and S. Zhang (2017). “Equilibrium Securitization with Diverse Beliefs”. *Working paper.*

Ennis, H. M. and A. L. Wolman (2015). “Large Excess Reserves in the United States: A View from the Cross-Section of Banks?” *International Journal of Central Banking* 11.1.

Farboodi, M., G. Jarosch, and G. Menzio (2017). *Intermediation as rent extraction*. Tech. rep. National Bureau of Economic Research.

Farhi, E. and J. Tirole (2015). "Liquid bundles". *Journal of Economic Theory* 158.PB, pp. 634–655.

Financial Stability Board (2013). *Global shadow banking monitoring report*. Tech. rep.

Fostel, A. and J. Geanakoplos (2012). "Tranching, CDS, and Asset Prices: How Financial Innovation Can Cause Bubbles and Crashes". *American Economic Journal: Macroeconomics* 4.1, pp. 190–225. DOI: 10.1257/mac.4.1.190.

Fulghieri, P., D. Garćia, and D. Hackbarth (2016). *Asymmetric information and the pecking (dis)order*. Tech. rep. UNC.

Gale, D. (1992). "A Walrasian theory of markets with adverse selection". *The Review of Economic Studies* 59.2, pp. 229–255.

Gale, D. and M. Hellwig (1985). "Incentive-compatible debt contracts: The one-period problem". *The Review of Economic Studies* 52.4, pp. 647–663.

Geanakoplos, J. (1997). "Promises, promises". *The economy as an evolving complex system II* 1997, pp. 285–320.

— (2001). "Liquidity, default and crashes: Endogenous contracts in general equilibrium".

— (2003). "Liquidity, default, and crashes endogenous contracts in general". In: *Advances in economics and econometrics: theory and applications: eighth World Congress*. Vol. 170.

Geanakoplos, J. and W. Zame (2002). *Collateral and the enforcement of intertemporal contracts*. Tech. rep. Yale University working paper.

Geromichalos, A., L. Herrenbrueck, and S. Lee (Nov. 2018). *Asset Safety versus Asset Liquidity*. Working Papers 326. University of California, Davis, Department of Economics. URL: https://ideas.repec.org/p/cda/wpaper/326.html.

Gorton, G., S. Lewellen, and A. Metrick (2012). "The Safe-Asset Share". *The American Economic Review* 102.3, pp. 101–106. ISSN: 00028282. URL: http://www.jstor.org/stable/23245512.

Gorton, G. and A. Metrick (2012a). "Securitized banking and the run on repo". *Journal of Financial Economics* 104.3, pp. 425–451.

Gorton, G. and G. Ordonez (2013a). *The Supply and Demand for Safe Assets*. Tech. rep. NBER.

— (2014). "Collateral crises". *American Economic Review* 104.2, pp. 343–78.

Gorton, G. and G. Pennacchi (1990). "Financial intermediaries and liquidity creation". *The Journal of Finance* 45.1, pp. 49–71.

Gorton, G. B. (2016). *The History and Economics of Safe Assets*. Tech. rep. NBER.

Gorton, G. B. and A. Metrick (2012b). *Who Ran on Repo?* Tech. rep. National Bureau of Economic Research.

Gorton, G. B. and G. Ordonez (Jan. 2013b). *The Supply and Demand for Safe Assets*. NBER Working Papers 18732. National Bureau of Economic Research, Inc. URL: `https://ideas.repec.org/p/nbr/nberwo/18732.html`.

Gottardi, P., V. Maurin, and C. Monnet (2017). "A theory of repurchase agreements, collateral re-use, and repo intermediation".

Greenwood, R., S. G. Hanson, and J. C. Stein (2015). "A Comparative-Advantage Approach to Government Debt Maturity". *Journal of Finance* LXX, pp. 1683–1722.

Haldane, A. et al. (Oct. 2016). *QE: The Story so far*. Bank of England working papers 624. Bank of England. URL: `https://ideas.repec.org/p/boe/boeewp/0624.html`.

Hellwig, M. (2009). "Systemic Risk in the Financial Sector: An Analysis of the Subprime-Mortgage Financial Crisis". *De Economist* 157, pp. 129–208.

Holmstrom, B. and J. Tirole (1998). "Private and Public Supply of Liquidity". *Journal of Political Economy* 106.1, pp. 1–40. ISSN: 00223808, 1537534X. URL: `http://www.jstor.org/stable/10.1086/250001`.

Holmström, B. and J. Tirole (2001). "LAPM: A liquidity-based asset pricing model". *the Journal of Finance* 56.5, pp. 1837–1867.

ICMA (2018). *European Repo Market Survey*. Tech. rep. International Capital Market Association.

International Capital Market Association (2013). "Frequently Asked Questions on repo". *http://www.icmagroup.org/Regulat Policy-and-Market-Practice/short-term-markets/Repo-Markets/frequently-asked-questions-on-repo/*.

Is There a U.S. High Cash Holdings Puzzle after the Financial Crisis? (2013). Working Paper Series. Ohio State University, Charles A. Dice Center for Research in Financial Economics. URL: `https://EconPapers.repec.org/RePEc:ecl:ohidic:2013-07`.

Jiang, E. et al. (Mar. 2020). *Banking without Deposits: Evidence from Shadow Bank Call Reports*. NBER Working Papers 26903. National Bureau of Economic Research, Inc. URL: `https://ideas.repec.org/p/nbr/nberwo/26903.html`.

Jiang, Z. et al. (2019). *The Government Risk Premium Puzzle*. Tech. rep. UNC.

Julliard, C. et al. (2018). *UK Repo Haircut*. Tech. rep. London School of Economics.

Jurek, J. W. and E. Stafford (2011). *Crashes and collateralized lending*. Tech. rep. National Bureau of Economic Research.

Kacperczyk, M. T., C. Perignon, and G. Vuillemey (2021). "The Private Production of Safe Assets". *The Journal of Finance* 76.2, pp. 495–535. DOI: https://doi.org/10.1111/jofi.12997. eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1111/jofi.12997. URL: https://onlinelibrary.wiley.com/doi/abs/10.1111/jofi.12997.

Kashyap, A., J. Stein, and D. Wilcox (1993). "Monetary Policy and Credit Conditions: Evidence from the Composition of External Finance". *American Economic Review* 83, pp. 78–98.

King, M. (2016). *The End of Alchemy: Money, Banking, and the Future of the Global Economy*. WW Norton & Company.

Kiyotaki, N. and J. Moore (1997). "Credit cycles". *Journal of Political Economy* 105.2, pp. 211–248.

Kiyotaki, N. and R. Wright (1989). "On Money as a Medium of Exchange". *Journal of Political Economy* 97.4, pp. 927–954. URL: https://ideas.repec.org/a/ucp/jpolec/v97y1989i4p927-54.html.

Krishnamurthy, A., Z. He, and K. Milbradt (2019). "A Model of Safe Asset Determination". *American Economic Review* 109.4, pp. 1230–1262.

Krishnamurthy, A., S. Nagel, and D. Orlov (2014). "Sizing up repo". *The Journal of Finance*.

Krishnamurthy, A. and A. Vissing-Jorgensen (Oct. 2011). *The Effects of Quantitative Easing on Interest Rates: Channels and Implications for Policy*. NBER Working Papers 17555. National Bureau of Economic Research, Inc. URL: https://ideas.repec.org/p/nbr/nberwo/17555.html.

— (2012). "The Aggregate Demand for Treasury Debt". *Journal of Political Economy* 120, pp. 233–267.

— (2015). "The impact of Treasury supply on financial sector lending and stability". *Journal of Financial Economics* 118.3, pp. 571–600. DOI: 10.1016/j.jfineco.2015.08. URL: https://ideas.repec.org/a/eee/jfinec/v118y2015i3p571-600.html.

Kuong, J. C.-F. (2017). "Self-fulfilling fire sales: Fragility of collateralised short-term debt markets".

Kurlat, P. (2013). "Lemons markets and the transmission of aggregate shocks". *American Economic Review* 103.4, pp. 1463–89.

Lagos, R. and R. Wright (2005). "A unified framework for monetary theory and policy analysis". *Journal of political Economy* 113.3, pp. 463–484.

Leland, H. E. and D. H. Pyle (1977). "Informational asymmetries, financial structure, and financial intermediation". *The journal of Finance* 32.2, pp. 371–387.

Lester, B., A. Postlewaite, and R. Wright (2012). "Information, liquidity, asset prices, and monetary policy". *The Review of Economic Studies* 79.3, pp. 1209–1238.

Li, Y., G. Rocheteau, and P.-O. Weill (2012a). "Liquidity and the Threat of Fraudulent Assets". *Journal of Political Economy* 120.5, pp. 815–846. DOI: 10.1086/668864. eprint: https://doi.org/10.1086/668864. URL: https://doi.org/10.1086/668864.

— (2012b). "Liquidity and the threat of fraudulent assets". *Journal of Political Economy* 120.5, pp. 815–846.

Martin, A., D. Skeie, and E.-L. Von Thadden (Oct. 2012). "The Fragility of Short-Term Funding Markets". *Journal of Economic Theory* 149. DOI: 10.2139/ssrn.2170882.

— (2014). "Repo runs". *Review of Financial Studies* 27.4, pp. 957–989.

Miao, J. and P. Wang (2018). "Asset bubbles and credit constraints". *American Economic Review* 108.9, pp. 2590–2628.

Modigliani, F. and R. Sutch (1966). "Innovations in Interest Rate Policy". *The American Economic Review* 56.1/2, pp. 178–197. ISSN: 00028282. URL: http://www.jstor.org/stable/1821281.

MOREIRA, A. and A. SAVOV (2017). "The Macroeconomics of Shadow Banking". *The Journal of Finance* 72.6, pp. 2381–2432. DOI: https://doi.org/10.1111/jofi.12540. eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1111/jofi.12540. URL: https://onlinelibrary.wiley.com/doi/abs/10.1111/jofi.12540.

Myers, S. C. and N. S. Majluf (1984a). "Corporate financing and investment decisions when firms have information that investors do not have". *Journal of Financial Economics* 13.2, pp. 187–221.

Myers, S. C. and N. S. Majluf (1984b). "Corporate Financing and Investment Decisions when Firms have Information that Investors Do Not Have". *Journal of Financial Economics* 13.2, pp. 187–221.

Nachman, D. C. and T. H. Noe (1994). "Optimal design of securities under asymmetric information". *The Review of Financial Studies* 7.1, pp. 1–44.

Ozdenoren, E., K. Yuan, and S. Zhang (2019). *Dynamic Coordination and Flexible Security Design*. Tech. rep. LBS and LSE.

Parlatore, C. (Forthcoming). "Collateralizing liquidity". *Journal of Financial Economics*.

Peirve, H. (2017). *Securities lending and the Untold Story in the Collapse of AIG*. Tech. rep. George Mason University, Mercatus Center Working Paper.

Peydró, J.-L., A. Polo, and E. Sette (2021). "Monetary policy at work: Security and credit application registers evidence". *Journal of Financial Economics* 140.3, pp. 789–814. ISSN: 0304-405X. DOI: https://doi.org/10.1016/j.jfineco.2021.01.008. URL: https://www.sciencedirect.com/science/article/pii/S0304405X21000313.

Plantin, G. (2009). "Learning by holding and liquidity". *Review of Economic Studies* 76.1, pp. 395–412.

Rehlon, A. and D. Nixon (2013). “Central counterparties: what are they, why do they matter and how does the Bank supervise them?” *Bank of England Quarterly Bulletin* 53.2, pp. 147–156.

Reis, R. (2017). “QE in the Future: The Central Bank?s Balance Sheet in a Fiscal Crisis”. *IMF Economic Review* 65.1, pp. 71–112. DOI: 10.1057/s41308-017-0028-2. URL: https://ideas.repec.org/a/pal/imfecr/v65y2017i1d10.1057_s41308-017-0028-2.html.

Rocheteau, G. (2011). “Payments and liquidity under adverse selection”. *Journal of Monetary Economics* 58.3, pp. 191–205.

Rytchkov, O. (2009). “Dynamic margin constraints”. *Work. Pap., Temple Univ.*

Samuelson, P. A. (1958). “An Exact Consumption-Loan Model of Interest with or without the Social Contrivance of Money”. *Journal of Political Economy* 66, pp. 467–467. DOI: 10.1086/258100. URL: https://ideas.repec.org/a/ucp/jpolec/v66y1958p467.html.

Simsek, A. (2013a). “Belief Disagreement and Collateral Constraints”. *Econometrica* 81.1, pp. 1–53.

— (2013b). “Belief disagreements and collateral constraints”. *Econometrica* 81.1, pp. 1–53.

Singh, M. (2011). *Velocity of pledged collateral: analysis and implications*. International Monetary Fund.

Stein, J. (2012). “Monetary Policy as Financial-Stability Regulation”. *Quarterly Journal of Economics* 127.1, pp. 57–95.

Swanson, E. T., L. Reichlin, and J. H. Wright (2011). “Let’s Twist Again: A High-Frequency Event-Study Analysis of Operation Twist and Its Implications for QE2 [with Comments and Discussion]”. *Brookings Papers on Economic Activity*, pp. 151–207. ISSN: 00072303, 15334465. URL: http://www.jstor.org/stable/41228525.

Valderrama, L. (2010). *Countercyclical regulation under collateralized lending*. Tech. rep. IMF Working Paper.

Wang, C. (2016). “Core-periphery trading networks”.

Yang, M. (Forthcoming). “Optimality of debt under flexible information acquisition”. *Review of Economic Studies*.