Bank Debt, Mutual Fund Equity, and Swing Pricing in Liquidity Provision*

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Abstract

Liquidity provision is often attributed to debt-issuing intermediaries like banks. We show that mutual funds issuing demandable equity also provide liquidity by insuring against idiosyncratic liquidity shocks. Quantitatively, the average bond fund provides 5.08 cents of liquidity per dollar, which is economically significant at one-fifth of that of banks. We find that fund liquidity provision is further improved by 6.7% when equity values incorporate the liquidation cost from redemptions, as in swing pricing. This is because swing pricing increases funds' capacity for holding illiquid assets without inducing panic runs.

Keywords: Swing Pricing, Mutual Funds, Liquidity Provision, Flows, Runs

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1 Introduction

A key function of financial intermediaries is liquidity provision. The literature has primarily attributed liquidity provision to banks, which issue demandable debt backed by a portfolio of illiquid assets (Diamond and Dybvig, 1983). However, financial intermediation has increasingly migrated beyond the traditional banking sector to intermediaries issuing demandable equity. In particular, U.S. fixed-income mutual funds saw their total assets increase from $0.5 trillion in 1995 to $4.5 trillion in 2019, which amounts to 35% of the banking sector's deposits in 2019 (Figure 1). This trend begs the question of whether liquidity provision is still only confined to debt-issuing intermediaries. After all, mutual funds also invest in illiquid assets like corporate bonds and issue shares redeemable at short notice.

We develop a framework for liquidity provision by debt- and equity-issuing intermediaries. We first establish that debt is not a prerequisite for liquidity provision. Theoretically, bond mutual funds that issue demandable shares also provide liquidity by allowing investors' idiosyncratic liquidity risks to be shared. Empirically, we construct the Liquidity Provision Index (LPI) as the first measure of liquidity provision that can be applied to both debt- and equity-issuing intermediaries, highlighting the interdependence of values and flows. The LPI captures how much an intermediary's contract payment value exceeds the direct liquidation value of the underlying assets without the intermediary, given any certain amount of flow. Taking the LPI to the data, we estimate that bond mutual funds provide an economically significant amount of liquidity at 5.08 cents per dollar, which is one-fifth of that of banks.

At the same time, the appropriate design and regulation of equity-funded intermediaries have been brought into the limelight by the Covid-19 crisis. In response to the large run-like redemptions at bond funds, the U.S. SEC has recently proposed to mandate swing pricing by open-end mutual funds.[1] Swing pricing adjusts a fund's net asset value (NAV) to pass on costs stemming from shareholder redemption activities to the redeeming shareholders. Larger outflows would thus lead to larger reductions in fund equity value to incorporate the cost of redemptions.

[1]The U.S. SEC has recommended open-end mutual funds to adopt swing pricing effective as of 2018 and further proposed to mandate it in November 2022. See https://www.sec.gov/news/press-release/2022-199.

A major concern regarding swing pricing is that liquidity provision to investors is hurt because redeeming investors receive less than the current NAV.[2] In contrast to this concern, we show that swing pricing may not constrain but can improve liquidity provision by reducing the need for holding large amounts of liquid assets in meeting redemption requests. Funds can then hold more illiquid assets and transform more liquidity. Our counterfactual suggests that U.S. fixed-income mutual funds would have provided 6.7% more liquidity had swing pricing been adopted from 2011 to 2017. These findings imply that swing pricing not only reduces fragility by preventing fund runs but may further enhance the capacity of fund liquidity provision.

We begin by formulating mutual fund liquidity provision under a unified framework with bank liquidity provision, in which intermediary investments, investor flows, and contract values are all endogenous. In the model, investors are subject to idiosyncratic liquidity shocks. Before these shocks realize, they make investment decisions (via an intermediary) between liquid cash and an illiquid long-term asset with pre-mature liquidation costs. Investors can pool their resources and jointly invest through a bank, which issues debt with a fixed payment, or a mutual fund, which issues equity whose value fluctuates with the underlying asset prices. We further consider fund equity with swing pricing, whose value not only responds to asset prices but also adjusts with outflows to incorporate liquidation costs.

We show that like bank debt, fund equity provides liquidity to investors. That is, investors expect to obtain more from redeeming early with their intermediary than by holding and selling the underlying assets themselves. The reason is that investors' idiosyncratic liquidity shocks are pooled at the intermediary level regardless of the contractual form, which allows less of the illiquid asset to be prematurely liquidated. The issuance of debt is therefore not a necessary condition for liquidity provision.

Importantly, we show that fund liquidity provision can be achieved in the absence of runs if equity value not only adjusts with the underlying asset prices but also with fund outflows, as in swing pricing. Our theory provides an equilibrium swing pricing adjustment to fund equity value that would allocate liquidation costs proportionately to redeeming investors given outflows. Although this adjustment swings fund equity values downwards with outflows, it may enhance rather than constrains liquidity provision in equilibrium. This is because the elimination of run

[2] For example, see ICI, "Swing Pricing Proposal From SEC Could Severely Harm Savers." https://www.ici.org/news-release/22-news-pan-swing-pricing.

incentives also reduces the fund's need for holding liquid cash, which allows the fund to hold more of the illiquid asset and transform more liquidity in equilibrium.

Based on the model, we derive the LPI as the first measure of liquidity provision that is applicable to various financial institutions regardless of the contractual form of their liabilities. The LPI requires three inputs: asset holdings, the liquidation costs of assets, and outflows. In each quarter, we calculate the contract payment given outflows for each institution. For banks, depositors obtain the face value of debt unless the bank defaults and the proceeds are distributed proportionately. For fund equity without swing pricing, redeeming investors obtain the NAV if the liquidation value of the underlying assets is sufficient to meet redemptions. Otherwise, the fund is liquidated and investors obtain a proportionate share of the liquidation value. With swing pricing, redeeming investors obtain an adjusted NAV that incorporates liquidation costs. Because swing pricing has not been implemented for U.S. mutual funds in our sample period, we adjust the distribution of outflows and the proportion of cash holdings following Jin, Kacperczyk, Kahraman and Suntheim (2022). Finally, we calculate the realized LPI as the percentage change between the contract payment from the intermediary and the liquidation value of the underlying portfolio, which reflects the intermediary's contribution to liquidity provision.

Overall, our LPI estimates show that fixed-income mutual funds provide an economically significant amount of liquidity. Over our sample period from 2011 to 2017, the average fund provides 5.08 cents of liquidity per dollar. In comparison, the average bank provides 27.47 cents of liquidity per dollar. In other words, a dollar invested in the average fixed-income mutual fund transforms around one-fifth of the liquidity as a dollar in bank deposits. In the time series, the gap in liquidity production capacity between banks and funds has increasingly narrowed from 2011 to 2017. We find evidence that the decline in the bank-fund LPI gap is associated with the expansion in central bank reserves following Quantitative Easing and the implementation of the Liquidity Coverage Ratio. Both policies increase the proportion of liquid assets on bank balance sheets, which shrinks the capacity for bank liquidity provision.

Fund liquidity provision could have been further improved had swing pricing been adopted. After adjusting fund outflows, fund asset composition, and contract payments, we find that swing pricing would improve liquidity provision for the majority of funds with the average fund experiencing an increase in LPI of 6.7%. Thus, swing pricing can simultaneously reduce fund fragility and increase fund liquidity provision.

We further consider the influence of several institutional features on LPI magnitudes. First, we project the LPI of a hypothetical zero deposit-insurance bank using the cross-sectional variation in LPIs and the ratio of insured deposits. We find that bank LPI drops from 27.47 to 20.91 cents per dollar in this case, which implies that funds provide about one-quarter of the liquidity of bank deposits absent deposit insurance. Second, we adjust fund LPIs to allow for partial NAV striking and obtain results very similar to our baseline. Third, we adjust LPIs to exclude fund fees and bank asset returns not distributed to depositors to obtain the LPI net of fees. Bank and fund LPIs slightly decrease in magnitude but fund liquidity provision per dollar remains at around one-fifth of that of banks.

Finally, we apply our LPI to money market funds (MMFs) around the 2016 Money Market Fund Reform to shed further light on the effect of demandable debt versus demandable equity funding on liquidity provision. The reform required institutional prime and tax-exempt MMFs to switch from fixed to floating NAVs, representing a transition from debt to equity funding. At the same time, retail prime MMFs were exempt from this requirement and provide a natural control group. Our estimates confirm that 91.4% to 93.3% of liquidity provision is preserved after the reform, corroborating the evidence from fixed-income funds that liquidity provision by demandable equity is lower than that by demandable debt but is still economically significant.

Taken together, our results have important policy implications for the design of demandable claims in liquidity transformation. We show that the flexible value of fund equity allows for but does not optimize liquidity provision because it cannot resolve panic runs. For example, although the MMF Reform changed the debt-like fixed NAV to an equity-like floating NAV, prime MMFs still used up significant liquidity buffers to meet large run-like redemptions during the Covid-19 crisis.[3] Similarly, pronounced outflows also materialized in U.S. bond mutual funds, which lead to a concentrated sale of their liquid asset holdings Ma, Xiao and Zeng (2021). We show that panic-driven outflows and asset sales could be prevented if funds could adjust their equity value with our proposed swing factor to incorporate the full cost of redemptions. In that case, the equilibrium level of fund liquidity provision could be further improved.

[3]See the Financial Stability Board, the *Holistic Review of the March Market Turmoil.* https://www.fsb.org/2020/11/holistic-review-of-the-march-market-turmoil/.

The theoretical literature on liquidity provision has mostly centered around deposit-issuing banks as in Diamond and Dybvig (1983), Diamond and Rajan (2001), Kashyap, Rajan and Stein (2002), and Goldstein and Pauzner (2005), for example. This literature highlights panic runs as the most important friction in bank liquidity provision. Indeed, Egan, Hortacsu and Matvos (2017) estimate that uninsured deposits are subject to runs. Hanson, Shleifer, Stein and Vishny (2015) consider debt claims issued by traditional banks versus shadow banks in liquidity provision.[4] We provide a unified framework to understand liquidity provision by both banks and funds. We theoretically and empirically show that demandable-equity-funded intermediaries can also provide a significant amount of liquidity.

Our focus on the role of equity-issuing financial intermediaries in liquidity provision speaks to the growing literature on the financial stability implications of open-end mutual funds. Fund asset illiquidity drives run-like behavior by fund investors, as shown by Chen, Goldstein and Jiang (2010), Feroli, Kashyap, Schoenholtz and Shin (2014), Goldstein, Jiang and Ng (2017), and Falato, Goldstein and Hortacsu (2021). Chernenko and Sunderam (2017, 2022) show that, to meet redemption requests, mutual funds investing in illiquid assets hold substantial amounts of cash, and consequently, the amount of cash holding can be used to infer the illiquidity of fund assets. Choi, Kronlund and Oh (2022) also find widespread stale pricing in bond mutual funds. Our theory formalizes the design features of fund equity, which allows us to explicitly specify how fund equity value should be adjusted to remove investors' first-mover advantage. Our model further endogenizes asset choice, which bears important implications for the capacity of fund liquidity provision under different design features of fund equity.

Our paper also contributes to the fast-growing literature on swing pricing. The rapidly expanding asset management industry and its vulnerabilities exposed by the Covid-19 crisis have led to an active debate on the pros and cons of adopting swing pricing, which the U.S. SEC has recently proposed to mandate for all open-end funds. Most closely related to our paper is Jin, Kacperczyk, Kahraman and Suntheim (2022). Using unique data on U.K. corporate bond funds, Jin, Kacperczyk, Kahraman and Suntheim (2022) provide the first empirical evidence that the adoption of swing pricing mitigates outflows during stress events and reduces fund

[4] A partial list of other papers on bank versus shadow bank liquidity includes Gorton and Metrick (2010), Kacperczyk and Schnabl (2013), Stein (2012), Sunderam (2015), Parlatore (2016), Li, Ma and Zhao (2020) and Xiao (2020).

cash holdings. Regarding fund NAV adjustments, Capponi, Glasserman and Weber (2020, 2022) model the feedback between mutual fund outflows and asset illiquidity to analyze the design of swing pricing given investor outflows. We develop a model in which the intermediary's asset choice and investors' outflows are determined endogenously depending on the design of fund equity. This framework allows us to shed light on how the adoption of swing pricing affects liquidity provision through equilibrium adjustments in fund assets and investor outflows.

Finally, we contribute to the measurement of liquidity provision. Prior work has focused on the banking sector (Berger and Bouwman, 2009, Brunnermeier, Gorton and Krishnamurthy, 2012, Bai, Krishnamurthy and Weymuller, 2018).[5] In recent work, Chernenko and Doan (2022) decompose liquidity creation by municipal bond funds using data available for the municipal bond market. We develop the first measure of liquidity provision that can be generally applied to demandable-debt- and demandable-equity-issuing financial institutions. The generality of the LPI stems from explicitly accounting for intermediaries' contract design across bank debt and various forms of demandable equity as well as the interdependence of values and flows. Among others, it allows us to examine how fund equity with swing pricing affects liquidity provision. The LPI can be estimated using commonly available data and provides a useful tool for monitoring the landscape of liquidity provision going forward.

The remainder of the paper is organized as follows. Section 2 lays out the theoretical framework for liquidity provision by debt- and equity-issuing intermediaries. Section 3 explains the LPI construction and Section 4 presents empirical results and Section 5 concludes.

2 Theoretical Framework

We build a theoretical framework in the spirit of Diamond and Dybvig (1983) to formalize the notion of liquidity provision by a financial intermediary issuing demandable claims. We consider bank deposits, which represent a debt contract, and mutual fund shares, which represent an equity contract. For fund equity, we further consider whether it uses swing pricing to determine the NAV of the fund. In particular, we formalize the notion of swing pricing by specifying which variables are contractable in the equity contract. The goal of the model is to compare

[5] In Section 3.4, we provide a detailed comparison of our LPI to the existing measures in this literature.

the constraints of liquidity provision under different contractual forms and to provide a unified measure of liquidity provision. The proofs are provided in Appendix A.

2.1 Model Setting and Primitives

The economy has three dates, $t = 0, 1, 2$. There is a $[0, 1]$ continuum of ex-ante identical agents, each endowed with one unit of a consumption good at $t = 0$, called "cash", which serves as the numeraire. Each agent is uncertain about her preferences over consumption at $t = 1$ and $t = 2$. At the beginning of $t = 1$, an agent learns her preferences privately: with probability $\pi \in (0, 1)$ she is an early-type and gets utility $u(c_1)$ from date-1 consumption only, while with probability $1-\pi$ she is a late-type and gets utility $u(c_2)$ from date-2 consumption only. Economically, π captures the magnitude of agents' idiosyncratic liquidity shocks. The primitive utility function, $u(c)$, is increasing, concave, and satisfies the Inada conditions. As such, agents face idiosyncratic risks. There is also a continuum of aggregate states realized at $t = 1$, denoted by R and distributed according to a distribution of $G(\cdot)$ with support $[1, +\infty)$. We call R the fundamentals of the economy. The consumption good, cash, can be consumed or transferred to the next date via one of two technologies: 1) a long-term, risky, and illiquid investment opportunity denoted as "asset", and 2) a short-term, riskless, and liquid asset denoted as "storage".

The long-term asset is risky, illiquid, and available for investment at $t = 0$ only. One unit of cash invested in the asset at $t = 0$ yields R units of cash at $t = 2$, where R is the aggregate state. Because $R \geq 1$, the asset generates a higher long-run expected return than stored cash.

At $t = 1$, the value of this long-term, illiquid asset differs from cash in two aspects. First, it has not yet come to fruition at $t = 1$ and yields a value of $\beta(R)$ if not traded, where $\beta(R)$ is an increasing function of R that satisfies $1 \leq \beta(R) < R$. The specification of $\beta(R)$ can be viewed as a generalization of Diamond and Dybvig (1983) in which $\beta(R) = 1$. It serves to capture the common feature of long-term assets such as corporate loans and corporate bonds that their short-term values may partially respond to economic fundamentals.[6]

Further, because the asset is illiquid, a liquidation cost will be incurred if it is prematurely liquidated at $t = 1$. Specifically, the unit liquidation cost is ϕ so that the liquidation value at

[6]We thank Doug Diamond for this suggestion of modeling the pre-mature value of the long-term asset.

$t = 1$ is $(1-\phi)\beta(R)$, where $0 < \phi \leq 1$ captures the extent of asset illiquidity. Below, we call ϕ as either liquidation cost or haircut. Economically, ϕ captures that the liquidation of loans and bonds in secondary markets can depress their prices (see Duffie, 2010, for a review). There is also a large empirical literature analyzing flow-induced liquidation costs for mutual funds (e.g., Edelen, 1999, Coval and Stafford, 2007, Choi, Hoseinzade, Shin and Tehranian, 2020, Jiang, Li, Sun, and Wang, 2022). The parameter ϕ may also capture negative real impacts, when liquidations of loans and bonds affect the capacity of corporates rolling over their debt (e.g. He and Xiong, 2012).

The order of play is as follows. At $t = 0$, all agents pool their endowments to collectively form a representative intermediary. The intermediary allocates the pool of endowments into the two assets and offers a demandable contract to agents, which we will elaborate on below. At $t = 1$, agents' idiosyncratic shock and the aggregate state of the economy realize. An early agent always leaves the intermediary at $t = 1$ regardless of R, while a late agent chooses whether to leave the intermediary depending on R and the intermediary's contract payment. We denote by λ the total number of agents who withdraw/redeem and leave the intermediary at $t = 1$. We also call λ outflows interchangeably. Finally, at $t = 2$, the asset matures, and the remaining proceeds are paid out according to the contracts.

The key novelty of our framework is to uncover the similarities and differences between bank debt and mutual fund equity in liquidity provision. To this end, we extend the classic model of Diamond and Dybvig (1983) by comparing three scenarios with different contractual arrangements at $t = 0$ given the same underlying economy.[7]

In all scenarios, the representative intermediary offers a contract in the form of (c_k, c'_k) to agents at $t = 0$, where c_k and c'_k denote the payments to agents at $t = 1$ and $t = 2$, respectively, and where the subscript $k \in \{b, f, s\}$ denotes the intermediary and contractual type: a bank (b) issuing debt, a fund (f) issuing equity, or a fund issuing equity with swing pricing (s). We focus on the date-1 contractual payment c_k because c'_k is subsequently determined by the intermediary's budget constraint. The intermediary also makes portfolio choices (x_k, y_k) at $t = 0$ on agents' behalf, where x_k is the amount of cash in storage and y_k is the amount of assets. Since the intermediary is representative, it maximizes agents' utility and breaks even in equilibrium.

[7]To focus on the effect of contractual differences on liquidity provision, we consider different contracts in parallel. We leave the competition and interaction between banks and funds for future research.

In the first scenario, the representative bank offers a standard demandable debt contract to agents at $t = 0$. The cash payment at $t = 1$, c_b, is fixed and does not depend on fundamentals R, unless the bank defaults, in which case the liquidation value of the intermediary is distributed on a pro-rata basis to all agents as in Allen and Gale (1998).

In the second scenario, the representative open-end mutual fund offers an equity contract whose payment depends on fundamentals. Specifically, the cash payment at $t = 1$ is given by

$$c_f(R) = x + y\beta(R)$$

if the fund is solvent, which is the NAV of the fund given the realized asset price $\beta(R)$ at the end of date 1. If the fund is liquidated, the liquidation value is distributed on a pro-rata basis to all agents. In this sense, fund NAV flexibly responds to fundamentals and represents an equity contract as opposed to a debt contract, but it does not internalize the full cost of redemptions.

This specification of fund equity is consistent with the practice of U.S. open-end mutual funds. Mutual funds calculate their NAVs once a day, typically at 4 p.m. EST, reflecting asset prices when the market closes. However, according to the SEC,[8] "trading activity and other changes in portfolio holdings associated with meeting redemptions may occur over multiple business days following the redemption request. If these activities occur in days following redemption requests, the costs of providing liquidity to redeeming investors could be borne by the remaining investors in the fund." In addition to the protracted time in transacting illiquid assets, another reason is the delayed reporting of redemption requests. In particular,"many current systems for processing fund orders are not set up to provide data on shareholder flows until well after a fund's NAV has already been struck, and that some of these systems depend on receiving the fund's NAV before the processing of shareholder purchase and redemptions transactions can begin." These observations are consistent with the fund equity contract in our model, where the amount of redemptions is not directly contractable.

In the third scenario, the representative open-end mutual fund offers an equity contract with a swing pricing feature, which allows the fund to further adjust its NAV to incorporate the extent of outflows and reflect the outflow-induced liquidation costs. In the U.S., the SEC has allowed

[8]See the U.S. SEC, the *Final Rule of Investment Company Swing Pricing*. https://www.sec.gov/rules/final/2016/33-10234.pdf

but not yet enforced the adoption of swing pricing by mutual funds. Formally, we model swing pricing by allowing the cash payment at $t = 1$, $c_s(R, \lambda)$, to depend not only on R but also on the number of agents redeeming at $t = 1$, λ, in order to incorporate any liquidation costs induced by agent redemptions at $t = 1$.

To formalize the mechanism underlying swing pricing, we provide the expression of $c_s(R, \lambda)$ below. Specifically, the representative fund that maximizes expected agent utility will first use its stored cash to meet redemptions at $t = 1$. Doing so avoids premature liquidation of the asset, which has a higher return when held until maturity. Hence, if the fund has enough stored cash to meet redemptions at the fund NAV, that is, if $x \geq \lambda(x + y\beta(R))$, no asset liquidations will occur, and consequently, the end-of-day NAV will still be:

$$c_s(R, \lambda) = x + y\beta(R)\,, \text{ if } x \geq \lambda(x + y\beta(R))\,, \tag{2.1}$$

where the per-unit value of stored cash is 1 and that of the illiquid asset is $\beta(R)$.

Instead, if the fund does not have enough stored cash in the sense that $x < \lambda(x + y\beta(R))$, it has to liquidate $l > 0$ units of the illiquid asset to help meet redemptions and implement swing its NAV downwards. This liquidation process implies that the end-of-day NAV has to jointly satisfy two conditions when $x < \lambda(x + y\beta(R))$, which pin down $c_s(R, \lambda)$ and l. First, swing pricing implies that the liquidation cost will be fully incorporated into the end-of-day NAV and proportionally borne by all agents:

$$c_s(R, \lambda) = x + (y - \phi l)\beta(R)\,, \text{ if } x < \lambda(x + y\beta(R))\,, \tag{2.2}$$

where l depends on λ in equilibrium. Second, because liquidation is costly, the fund liquidates just enough of the illiquid asset to meet redemption requests at the end-of-day NAV after using swing pricing. In other words, the total amount of cash distributed to λ redeeming agents is the sum of stored cash and that raised from costly liquidations:

$$\lambda c_s(R, \lambda) = x + (1 - \phi)l\beta(R)\,, \text{ if } x < \lambda(x + y\beta(R))\,. \tag{2.3}$$

The solution to equations (2.2) and (2.3) pins down $c_s(R, \lambda)$ when $x < \lambda(x + y\beta(R))$.

With the above three intermediary and contractual arrangements, we consider optimal debt and equity contracts that are most closely aligned with those in practice, i.e., demandable deposits and open-end mutual fund shares. In this sense, we analyze constrained optimal debt and equity contracts instead of a mechanism design problem over a general contract space.[9] Note that the fund equity contracts, with or without swing pricing, are different from Jacklin (1987) and the broader literature that explores how tradable contracts in financial markets provide liquidity (e.g., Allen and Gale, 2004, Farhi, Golosov and Tsyvinski, 2009). The key feature of the fund equity contracts that we consider is demandability rather than tradability, which is consistent with open-ended funds in practice. We also note that the bank debt contract in our framework differs from the literature that studies the role of bank deposits as a means of payment (e.g., Donaldson, Piacentino and Thakor, 2018, Parlour, Rajan and Walden, 2022).

Before analyzing the three contracts, we first define a benchmark liquidation value of how much short-term consumption an agent can obtain by liquidating a given portfolio at short notice in the absence of an intermediary.

Definition 1. *Given any portfolio (x, y), its liquidation value at $t = 1$ is given by*

$$c(x, y) = x + y(1 - \phi)\beta(R)\,. \tag{2.4}$$

Intuitively, the portfolio's liquidation value is lower when the portfolio is more illiquid.

We then define liquidity provision as the net percentage difference between the expected intermediary contract payment and the liquidation value of the underlying portfolio.

Definition 2. *For a dollar invested in an intermediary holding a portfolio of (x_k, y_k) and issuing contract $k \in \{b, f, s\}$, the amount of liquidity provision is defined as the Liquidity Provision Index (LPI):*

$$LPI_k = \frac{c_k^*(R, \lambda),}{c(x_k, y_k)} - 1\,, \tag{2.5}$$

[9]Another reason we do not consider a generally optimal contract is because such a contract is not observed in reality. For an unconstrained optimal contract, notice that a social planner who can verify agents' types, once realized, and who has the same almost perfect signal about fundamentals R as the agents have, would set the date-1 consumption level c of the early agents to maximize the ex-ante expected welfare. This implies that the early agent's marginal utility at c will be equal to the marginal utility of late agents at (the endogenously determined) c' at any given realized R, which means that the unconstrained optimal contract must depend on the specific utility function.

where the contract payment $c_k^*(R,\lambda)$ is determined in equilibrium given the intermediary contractual arrangement and the underlying economy, and $c(\cdot,\cdot)$ is the liquidation value function as defined in Definition 1. Accordingly, the expected amount of liquidity provision is defined as the expected LPI,

$$\mathbb{E}[LPI_k^*] = \int_{[1,+\infty)} \left(\frac{c_k^*(R,\lambda)}{c(x_k^*, y_k^*)} - 1 \right) dG(R)\,, \tag{2.6}$$

where the optimal intermediary portfolio holdings (x_k^*, y_k^*) are determined in equilibrium.

Definition 2 indicates that the per-dollar amount of liquidity provided to an agent subject to a liquidity shock is affected by both sides of the intermediary's balance sheet. Liquidity provision captures the percentage difference between the contract payment (the liability side of the intermediary) and the liquidation value of the underlying portfolio (the asset side of the intermediary). It is positive if the claims issued by the intermediary have a higher value upon liquidation at short notice than the underlying assets it holds.

Our definition of liquidity provision has several advantages. Theoretically, it is consistent with the notion of liquidity provision in Diamond and Dybvig (1983) for banks and allows for a unified comparison across debt- and equity-issuing financial intermediaries.[10] Empirically, all essential inputs for the calculation are observable, which allows for a direct application of the model to quantify liquidity provision. Finally, as presented in equations (2.5) and (2.6), the amount of liquidity provision can be calculated from both an ex-post and ex-ante point of view, which allows for the comparison of liquidity provision under different scenarios. The expected LPI is better suited for comparing the average liquidity provided by different intermediaries, while the realized LPI is best for tracking the evolution of liquidity provision by the intermediary over time.

2.2 Liquidity Provision in Equilibrium

We first examine how the design of fund equity contracts affects panic runs. It is well known that demandable debt subjects a bank to panic runs because debt promises a fixed value that leads

[10] Consistent with Diamond and Dybvig (1983), Definition 2 focuses on consumption by early agents that are subject to liquidity shocks. It does not represent the overall welfare provided, which is an interesting but separate normative question that we leave for future research.

to a first-mover advantage. One may expect that equity, whose value is flexible and responds to fundamentals, is free from panic runs. Our result shows that the logic is more subtle:

Lemma 1. *Given the intermediary portfolio allocation* (x, y)*:*

i). Fund equity without swing pricing $c_f(R)$ *subjects the fund to panic runs at* $t = 1$ *in the sense that the two equilibria of* $\lambda^* = \pi$ *and* $\lambda^* = 1$ *co-exist. As a benchmark, bank debt* c_b *also subjects the bank to panic runs.*

ii). Fund equity with swing pricing $c_s(R, \lambda)$ *eliminates panic runs in the sense that there is no first-mover advantage among investors and* λ^* *is unique for any given* R*.*

Lemma 1 shows that even fund equity whose value flexibly adjusts with the underlying fundamentals remains susceptible to runs. Fund equity eliminates panic runs if and only if its value further depends on the number of redeeming agents, as in the case of full swing pricing. This is because the standard equity contract responds to fundamentals but not liquidation costs from redemptions, and thus still gives a first-mover advantage to redeeming agents just as bank debt does. In contrast, fund equity with swing pricing allows redeeming agents to proportionately share the liquidation costs that their redemptions induce, thereby eliminating the first-mover advantage and the potential for runs.

Since Diamond and Dybvig (1983), it is widely perceived that the potential for panic runs goes hand in hand with the use of debt. Chen, Goldstein and Jiang (2010) show that mutual funds investing in illiquid assets suffer from more outflows when experiencing bad performance, which points to the existence of panic runs. Compared to the existing literature, Lemma 1 precisely shows what features of equity can and cannot prevent runs. By highlighting the separate contractability of economic fundamentals and investor redemptions, our analysis shows that what matters for the run vulnerability of open-end mutual funds is not how NAVs respond to economic fundamentals, but how NAVs respond to redemption requests and the induced liquidation costs. This new modeling approach thus allows us to formulate the use of swing pricing in mutual funds, showing that a successful design of swing pricing should necessarily condition on the information about the amount of redemptions and liquidation costs but not just economic fundamentals.

Next, we explicitly characterize the magnitude of liquidity provision by the three contractual arrangements based on (2.5) in Definition 2.

Proposition 1. *Given any equilibrium intermediary portfolio allocation* (x, y)*, face value of bank debt* c_b*, outflows* λ*, and economic fundamentals* R*:*

i). The LPI for fund equity is given by

$$LPI_f = \begin{cases} \dfrac{x + y\beta(R)}{x + (1-\phi)y\beta(R)} - 1 & \lambda \leq \dfrac{x + (1-\phi)y\beta(R)}{x + y\beta(R)}, \\ 0 & \lambda > \dfrac{x + (1-\phi)y\beta(R)}{x + y\beta(R)}. \end{cases} \tag{2.7}$$

ii). The LPI for fund equity with swing pricing is given by

$$LPI_s = \begin{cases} \dfrac{x + y\beta(R)}{x + (1-\phi)y\beta(R)} - 1 & \lambda \leq \dfrac{x}{x + y\beta(R)}, \\ \dfrac{1}{1 - (1-\lambda)\phi} - 1 & \lambda > \dfrac{x}{x + y\beta(R)}. \end{cases} \tag{2.8}$$

iii). As a benchmark, the LPI for bank debt is given by

$$LPI_b = \begin{cases} \dfrac{c_b}{x + (1-\phi)y\beta(R)} - 1 & \lambda \leq \dfrac{x + (1-\phi)y\beta(R)}{c_b}, \\ 0 & \lambda > \dfrac{x + (1-\phi)y\beta(R)}{c_b}. \end{cases} \tag{2.9}$$

Proposition 1 offers a unified account to understand the nature and magnitude of liquidity provision by fund equity, fund equity with swing pricing and bank debt. Specifically, the LPI expression (2.7) indicates that a mutual fund using equity provides liquidity to its investors because it helps investors pool their idiosyncratic risks. As shown in the first line of (2.7), redeeming investors get the fund NAV at $x + y\beta(R)$ as long as the fund is solvent, which is larger than what they would have gotten by liquidating the same underlying assets at $x + y(1 - \phi)\beta(R)$. In comparison, a bank using debt provides liquidity in the same way as shown in the LPI expression (2.9). Thus, the use of debt is not a prerequisite for liquidity provision. The comparison between (2.7) and (2.9) also echoes the fact that fund equity without swing pricing is subject to runs in liquidity provision just as bank debt is. When panic runs happen, agents only get the liquidation value of the underlying assets, and thus no liquidity is provided.

The LPI expression (2.8) suggests that the use of swing pricing allows fund equity to provide liquidity in a more continuous way. Specifically, the first line of (2.8) shows that if cash is sufficient to meet redemptions at the end-of-day NAV, the fund deploys cash without adjusting its NAV, and the same liquidity is provided as if the fund does not use swing pricing. As more agents redeem and cash is used up, the fund uses swing pricing by continuously adjusting its end-of-day NAV down to incorporate the resulting liquidation costs. This implies a continuously lower LPI as shown in the second line of (2.8). Notably, the LPI for fund equity with swing pricing is always continuous in λ, as opposed to that for fund equity which features a discontinuous jump. To illustrate these ideas, Figure 2 compares the LPIs of fund equity with swing pricing (solid line) and without swing pricing (dashed line), using the simple case of $\beta(R) = 1$.

Proposition 1 also allows us to characterize the swing factor, which is the amount, in percentage, by which a fund's NAV is adjusted down after redemptions. In our framework, the swing factor can be formally defined as the following:

Definition 3. *The swing factor $k(\lambda)$ of a fund which uses swing pricing and which has a portfolio allocation of (x, y) is given by*

$$c_s(R, \lambda) = (1 - \kappa(\lambda))(x + y\beta(R)) \,.$$

Intuitively, for a given level of outflow λ, the end-of-day NAV, $c_s(R, \lambda)$, is adjusted down from the initial NAV, $x + y\beta(R)$, by a percentage of $\kappa(\lambda)$. In equilibrium, Proposition 1 immediately implies that the equilibrium swing factor of a fund that uses swing pricing is given by

$$1 - \kappa(\lambda) = \begin{cases} 1 & \lambda \leq \dfrac{x}{x + y\beta(R)} \,, \\ \dfrac{1}{1 - (1 - \lambda)\phi} \cdot \dfrac{x + (1 - \phi)y\beta(R)}{x + y\beta(R)} & \lambda > \dfrac{x}{x + y\beta(R)} \,. \end{cases} \tag{2.10}$$

Here, the first line of (2.10) implies that the fund NAV will not be adjusted if flows are small so that no liquidation cost occurs. To understand the economic intuition of the second line, notice that the maximum swing factor $\kappa(1)$ as all agents redeem can be characterized by

$$1 - \kappa(1) = \frac{x + (1 - \phi)y\beta(R)}{x + y\beta(R)} \,,$$

which is the second term in the second line of (2.10). This term captures that every agent will only get the liquidation value $c(x, y) = x + (1 - \phi)y\beta(R)$ if all agents redeem resulting in the maximum outflows. Thus, as fewer agents redeem, the fund adjusts the NAV down less aggressively, and more so when the liquidation cost ϕ is lower, as captured by the first term in the second line of (2.10).

Our formulation of swing pricing and the swing factor incorporates all liquidation costs that directly arise from redemptions at the fund level. In the standard Diamond and Dybvig (1983) setting, this adjustment corrects the externalities imposed and removes any first-mover advantage among investors. In practice, there may be further externalities from funds' activities over time and their interactions with each other. For example, there may be costs from fund portfolio rebalancing and cash re-building going forward (Zeng, 2019), from fund managers' compensation benchmarking (Feroli, Kashyap, Schoenholtz and Shin, 2014), and from correlated asset sales by other funds (Falato, Goldstein and Hortacsu, 2021). In these more complex settings, the specification of the swing factor would involve more inputs such as the compensation contract of fund managers and the overlap of funds' asset portfolio holdings to incorporate the full costs of redemptions. We leave this dynamic multi-fund extension for future research.

2.3 Effects of Swing Pricing on Liquidity Provision

We now compare the magnitude of expected liquidity provision by fund equity with and without swing pricing in equilibrium, as defined in (2.6) in Definition 2. This analysis sheds new light on the commonly perceived concern that less liquidity may be provided with swing pricing as redeeming investors may receive less than the current asset values. We show that this argument is incomplete because it does not take into account the equilibrium effect on outflows and the asset holdings of the fund.

Formally, we solve the intermediary's problem at $t = 0$. Following the long literature on bank runs (e.g, Cooper and Ross, 1998, Davila and Goldstein, 2022), we assume that a sunspot coordinates agents' decisions at $t = 1$ in the sense that the run equilibrium $\lambda^* = 1$ happens with probability $q \in (0,1)$ when multiple equilibria exist.[11] Under the same economic environment captured by agents' utility function $u(\cdot)$, the distribution of fundamentals $G(\cdot)$, the pre-mature value function $\beta(\cdot)$, and the unit liquidation cost ϕ, we have the following proposition. Notably, the result only depends on the nature of fund equity being vulnerable to runs as shown in Lemma 1, but does not depend on the magnitude of the run probability q.

Proposition 2. *Fund equity with swing pricing allows the fund to hold more illiquid assets and provides higher liquidity in expectation compared to that without swing pricing, that is,* $y_s^* > y_f^*$ *and* $\mathbb{E}[LPI_s^*] > \mathbb{E}[LPI_f^*]$*, when the unit liquidation cost* ϕ *is sufficiently high and when the fraction of early agents* π *is sufficiently low.*

Proposition 2 contributes to the literature by pointing to the effectiveness of swing pricing in mitigating financial stability risks in mutual funds without hurting their core function of liquidity provision. The intuition underlying Proposition 2 is as follows. Recall from Lemma 1 that swing pricing eliminates panic runs. Thus, late agents are more likely to stay until $t = 2$ if the fund equity contract has the swing pricing feature, reducing the need for the fund to pre-maturely liquidate the illiquid asset at $t = 1$. Consequently, as long as the fund holds some cash before the adoption of swing pricing (i.e., $x_f^* > 0$ and $y_f^* < 1$, ensured by the first sufficient condition that liquidation cost ϕ is sufficiently high), the fund will optimally hold less cash and a larger fraction of the illiquid asset after the adoption of swing pricing (i.e., $y_s^* > y_f^*$). Proposition 2 thus provides a theoretical foundation for the empirical findings in Jin, Kacperczyk, Kahraman and Suntheim (2022) that mutual funds hold lower liquid buffers and more illiquid assets after the adoption of swing pricing.

Furthermore, a larger fraction of illiquid asset holdings implies that, according to Definition 1, the liquidation value of the entire fund portfolio becomes lower. A lower liquidation value may eventually translate into a higher expected liquidity provision, which captures the improvement of the contract payment from the liquidation value of the underlying asset portfolio. This improvement materializes as long as agents' liquidity shocks are sufficiently idiosyncratic, which is ensured by the second sufficient condition that the fraction of early agents π is not too high.[12]

[11] We could have also followed the global-game approach (e.g., Goldstein and Pauzner, 2005) to endogenize q, but that would significantly complicate the model without affecting the main insights because our results in Proposition 2 do not depend on the magnitude of q.

[12] Another way to understand the second sufficient condition of Proposition 2 is to examine the extreme case of $\pi = 1$. When $\pi = 1$, all agents are early and have to consume at $t = 1$, which is observationally equivalent to

2.4 Fund Equity with Partial NAV Striking

We further extend our baseline model to accommodate the potential for mutual funds to partially strike their NAVs without adopting swing pricing. As described by Pozen and Hamacher (2011), NAV striking is a practice in the mutual fund industry in which fund managers form an estimated amount of redemption requests, perform the necessary asset transactions, and pre-calculate the end-of-day NAV. Specifically, we model the fund partially striking the NAV in that it incorporates a fraction μ of the liquidation costs into the NAV, where $0 < \mu < 1$. As a result, the fund NAV at $t = 1$ is given by

$$NAV_1 = x + (y - \mu\phi l)\beta(R)\,, \tag{2.11}$$

where l denotes the amount of asset being liquidated at $t = 1$. When $\mu = 1$ ($\mu = 0$), this NAV formula converges to the baseline case with fund equity with (without) swing pricing. Following the same logic as in Proposition 1, the LPI for fund equity with partial NAV-striking is given by:

Proposition 3. *Given any equilibrium fund portfolio allocation* (x, y)*, outflows* λ*, and economic fundamentals* R*, the LPI for fund equity with partial NAV striking is given by*

$$LPI_{f;\mu} = \begin{cases} \dfrac{x + y\beta(R)}{x + y(1-\phi)\beta(R)} - 1 & \lambda \le \dfrac{x}{x + y\beta(R)}\,, \\ \dfrac{1}{1 - (1 - \mu\lambda)\phi} - 1 & \dfrac{x}{x + y\beta(R)} < \lambda \le \dfrac{x + y(1-\phi)\beta(R)}{x + y(1-\mu\phi)\beta(R)}\,, \\ 0 & \lambda > \dfrac{x + y(1-\phi)\beta(R)}{x + y(1-\mu\phi)\beta(R)}\,. \end{cases} \tag{2.12}$$

Moreover, for any $\mu < 1$*, fund equity with partial NAV striking subjects the fund to panic runs at* $t = 1$ *in the sense that the two equilibria of* $\lambda^* = \pi$ *and* $\lambda^* = 1$ *co-exist.*

The economic insights underlying Proposition 3 are two-fold. First, it shows that the use of partial NAV striking does not affect the unified conceptualization of liquidity. Given μ, the explicit LPI formula (2.12) depends on the same economic observables as those presented in the three LPI formulas (2.7), (2.8), and (2.9) in Proposition 1. Proposition 3 thus allows us to perform a sensitivity analysis to quantify the impact of partial NAV striking on liquidity provision and to compare it to the benchmarks with and without swing pricing. Second, it

a run equilibrium. As such, agents' idiosyncratic liquidity shocks cannot be shared. No liquidity can be provided even if the fund uses equity with swing pricing because the contract payment equals to the liquidation value.

further strengthens Lemma 1: even if a fund partially strikes its NAV, panic runs may still arise unless the fund NAV fully incorporates liquidation costs under full swing pricing.

3 Liquidity Provision Index (LPI)

We explain how the LPI can be constructed from commonly available data to provide an empirical quantification of liquidity provision by various financial intermediaries. We first illustrate the construction using a simple example in Section 3.1 and then provide a generalized step-by-step explanation in Section 3.2. Finally, we discuss the data sources in Section 3.3.

3.1 An Example

We illustrate the empirical construction of fund LPIs with reference to Proposition 1 and Figure 2. Suppose there is a mutual fund that holds 10% cash and 90% of corporate bonds, where cash is liquid while corporate bonds are illiquid with a haircut of 30%. That is, corporate bonds can only be converted to 70% of their fair value upon liquidation at short notice. Consider an investor that holds one share of the fund with an NAV of \$1. In the absence of the fund, if the investor has a liquidity shock and liquidates the underlying portfolio at short notice, she receives $1 \times \$0.1 + (1 - 30\%) \times \$0.9 = \$0.73$. However, if she holds the portfolio through the fund, then as long as not all investors redeem at the same time, idiosyncratic liquidity risk can be pooled at the fund level. This pooling of liquidity risk reduces liquidation costs and improves the amount of cash that investors can obtain at short notice. For example, if total outflows amount to less than 10% of the fund's assets, they can be met by just using the fund's cash so that no liquidation costs are incurred. Even if outflows exceed 10% and some illiquid assets are sold, investors can still redeem at the NAV of \$1 as long as outflows remain below 73% and can be fully met using the liquidation proceeds. In both cases, the realized LPI is $1/0.73 - 1 = 0.37$, following the first line of (2.7) in Proposition 1. However, if a panic run occurs and more than 73% of investors redeem at the same time, the fund cannot meet all the outflows at the NAV and will fully liquidate. Each investor receives \$0.73 and thus no liquidity is provided. That is, the realized LPI is $0.73/0.73 - 1 = 0$, following the second line of (2.7) in Proposition 1. This pattern for fund LPI corresponds to the dashed line in Figure 2.

In contrast, consider a swing-pricing fund with identical assets. If outflows are below 10%, cash is sufficient to meet outflows. Thus, the NAV is \$1 and the LPI is still $1/0.73 - 1 = 0.37$, following the first line of (2.8) in Proposition 1. If outflows exceed 10%, the fund starts to liquidate corporate bonds and uses swing pricing to adjust its NAV to reflect the liquidation costs that increase with outflows. For instance, if outflows reach 73%, the realized LPI is $1/(1 - (1 - 73\%) \times 30\%) - 1 = 0.09$ following the second line of (2.8) in Proposition 1. This pattern of LPI for fund equity with swing pricing corresponds to the solid line in Figure 2. We note that swing pricing in practice would also change funds' asset composition and investors' outflows because the risk of panic runs is eliminated (Propositions 1 and 2). Our empirical construction considers both adjustments, as we elaborate in the next subsection.

3.2 Construction of LPIs

As illustrated by the example above, one advantage of our unified framework of liquidity provision is the tight link between the theoretical foundation and its empirical counterpart. Formally, we show how the LPIs derived in Proposition 1 can be empirically constructed using observed data including intermediaries' portfolio holdings, the haircuts of different assets, and outflows. In this process, we generalize the baseline model in Section 2 to accommodate multiple assets as financial intermediaries invest in a range of different asset classes in practice. The detailed derivations for the multi-asset extension are provided in Appendix B.

Suppose there are $N \geq 1$ illiquid assets. Assets are ranked by their unit liquidation cost, that is, haircut: $0 < \phi_1 \leq \phi_2 \leq ... \leq \phi_N$, and their pre-mature value at $t = 1$ is denoted by $\beta_j(R)$ for asset j. Conveniently, we consider cash as asset 0 with $y_0 = x$, $\phi_0 = 0$ and $\beta_0(R) = 1$. Under this generalization, we can write the initial portfolio allocation at $t = 0$ as an $N+1$ vector $(y_0, y_{1,} y_{2,}..., y_N)$ with $\sum_{j=0}^{N} y_j = 1$. Then, we can express the portfolio weight (by value) of asset j at $t = 1$ as

$$w_j = \frac{y_j \beta_j(R)}{\sum_{j=0}^{N} y_j \beta_j(R)}, \tag{3.1}$$

which also satisfies $\sum_{j=0}^{N} w_j = 1$. Note that we do not need to separately estimate fundamentals R because this information is already incorporated in observed portfolio weights w_j.

3.2.1 Fund Equity without Swing Pricing

First, we empirically construct the LPI for fund equity without swing pricing. Generalizing (2.7) in Proposition 1 to the multi-asset case following the derivations in Appendix B.1, we derive the LPI for fund equity as follows:

$$LPI_f = \begin{cases} \dfrac{1}{1-\overline{\phi}} - 1 & \lambda \leq 1-\overline{\phi}\,, \\ 0 & \lambda > 1-\overline{\phi}\,, \end{cases} \tag{3.2}$$

where

$$\overline{\phi} = \sum_{j=0}^{N} w_j \phi_j \tag{3.3}$$

is the value-weighted average haircut of the observed fund portfolio.

The empirical LPI formula (3.2) only requires data on portfolio holdings w_j, asset haircuts ϕ_j, and fund outflows λ. The formula also admits an intuitive interpretation. According to Definition 1, $1-\overline{\phi}$ captures the per dollar liquidation value of the fund portfolio. The first line shows that when redemptions are less than the liquidation value of the portfolio, the fund can meet redemptions at the end-of-day NAV before incorporating any liquidation costs. In this case, liquidity is provided: for each dollar that an investor would have gotten by holding and liquidating the underlying portfolio without a mutual fund, she now enjoys $\frac{1}{1-\overline{\phi}} > 1$ by investing in the mutual fund and redeeming the shares. In contrast, the second line implies that no liquidity is provided if fund outflows are so large that redemption requests cannot be met at the end-of-day NAV. The fund fully liquidates and the LPI discontinuously drops to zero.

As discussed in Section 2.4, mutual funds in practice may also use partial NAV striking when calculating their end-of-day NAVs. We provide an adjustment of (3.2) to accommodate this possibility and explain the details of the construction in Appendix B.4. We also consider that mutual funds collect management fees in practice and repeat our fund LPI construction by deducting these fees from the fund contract payment.[13] We report these results in Section 4.1.

3.2.2 Fund Equity with Swing Pricing

We next construct the LPI for fund equity with swing pricing. Generalizing (2.8) in Proposition 1 following the derivations in Appendix B.2, we derive the LPI of fund equity with swing pricing as:

$$LPI_s = \frac{1}{1-\overline{\phi}} \cdot \underbrace{\frac{\sum_{j=0}^{J-1}(1-\phi_j)w_j + \sum_{j=J}^{N}(1-\phi_J)w_j}{1-(1-\lambda)\phi_J}}_{1-\text{swing factor}} - 1 \text{ when } \lambda_{J-1} < \lambda \leq \lambda_J, \tag{3.4}$$

where $\overline{\phi}$ is given by (3.3), $\lambda_{-1} = 0$, and

$$\lambda_J = \frac{\sum_{j=1}^{J}(1-\phi_j)w_j}{\sum_{j=1}^{J}(1-\phi_j)w_j + \sum_{j=J+1}^{N} w_j}, \text{ for } 0 \leq J \leq N,$$

in which J is the marginal asset being liquidated given outflows λ_J.

A comparison with (3.2) helps to uncover the intuition underlying (3.4). When liquidity is provided, the LPI for fund equity with swing pricing differs from that without swing pricing by the swing factor, which is a generalization of (2.10). Intuitively, for any given outflow λ, the fund liquidates the most liquid asset before moving on to sell its next liquid asset. In this process, the NAV continuously adjusts downwards to incorporate the liquidation costs. Accordingly, the swing factor depends on all the asset haircuts up to the marginal asset J that is liquidated to meet redemptions.

Although the construction of LPI with swing pricing also uses data on fund asset composition and investor outflows, these are the fund asset composition and investor outflows that would have

[13] Specifically, we adjust the LPI formula (3.2) to

$$LPI_f = \begin{cases} \frac{1-\kappa}{1-\overline{\phi}} - 1 & \lambda \leq 1-\overline{\phi}, \\ 0 & \lambda > 1-\overline{\phi}, \end{cases}$$

where κ is the percentage fees including management fee and 12b-1 fee, and where $\kappa < \overline{\phi}$.

been observed in the presence of swing pricing. Unfortunately, these changes are not observable to us because swing pricing for U.S. mutual funds has not been implemented in our sample period. To overcome this challenge, we adapt the findings from Jin, Kacperczyk, Kahraman and Suntheim (2022), who study mutual funds in several European jurisdictions that have implemented swing pricing rules over the past few decades. Guided by Propositions 1 and 2, we adjust funds' portfolio weights and outflows. Specifically, Jin, Kacperczyk, Kahraman and Suntheim (2022) find that the proportion of cash and cash equivalents, including Treasuries, agency debt, and agency MBS, drops by 3.26% with swing pricing. Accordingly, we reduce the proportion of cash and cash equivalents for our sample of funds and scale up the remaining portfolio proportionately. If the observed proportion of cash and cash equivalents is below 3.26%, we set it to zero. Jin, Kacperczyk, Kahraman and Suntheim (2022) also find that funds experience less volatile outflows with swing pricing. We adjust the observed flow distribution conditional on being in market stress following their estimates.[14] Our results are reported in Section 4.2.

3.2.3 Bank Debt

Finally, we empirically construct the LPI for bank debt. Compared to the LPIs for fund equity, the main challenge for bank debt is that the debt payment c_b for a Diamond-Dybvig-style bank is not empirically observable. In our baseline specification, we set the debt payment c_b to be the expected value of bank portfolio holdings, i.e., $c_b = \sum_{j=0}^{N} \mathbb{E}\left[\beta_j y_j\right]$. This specification highlights that debt payments do not respond to the realization of fundamentals by taking the expectation of asset values in the period before they realize. It also allows for a fair comparison between banks and funds, consistent with the Diamond-Dybvig framework in which all surplus created by financial intermediaries is passed on to investors. With this formulation, we generalize the LPI of bank debt from (2.9) in Proposition 1 to

[14] Specifically, following their estimates in Panel B of Table 3, we shift the flows from the 0^{th} to the 0.75^{th} percentile by 36%, flows from the 0.75^{th} to the 3^{rd} percentile by 24%, flows from the 3^{rd} to the 7.5^{th} percentile by 24%, flows from the 7.5^{th} to the 17.5^{th} percentile by 15%, flows from the 17.5^{th} to the 37.5^{th} percentile by 0%, and flows above the 37.5^{th} percentile by 0%, when the monthly VIX exceeds the 75^{th} percentile. When the monthly VIX is below the 75^{th} percentile, we shift the flows from the 0^{th} to the 0.75^{th} percentile by -18%, flows from the 0.75^{th} to the 3^{rd} percentile by -15%, flows from the 3^{rd} to the 7.5^{th} percentile by -15%, flows from the 7.5^{th} to the 17.5^{th} percentile by -9%, flows from the 17.5^{th} to the 37.5^{th} percentile by -6%, and flows above the 37.5^{th} percentile by 0%. We multiply the coefficients by 3 to convert from monthly flows to quarterly flows.

$$LPI_b = \begin{cases} \frac{1}{1-\overline{\phi}'} - 1 & \lambda \leq 1 - \overline{\phi}' \\ 0 & \lambda > 1 - \overline{\phi}', \end{cases} \tag{3.5}$$

where

$$\overline{\phi}' = \sum_{j=0}^{N} w_j' \phi_j$$

is the value-weighted average haircut of the portfolio. The portfolio weights w_j' are defined as the value of each asset over the expected asset value of the portfolio, the derivation and expression of which are given in Appendix B.3. Empirically, we use two proxies for the expected values of bank asset holdings in period t, including contemporaneous asset values in period t and lagged asset values in period $t-1$. We find that these approaches yield very similar magnitudes of bank LPIs. We present the results in Section 4.3.

Our formulation of bank LPI comes with a few assumptions. First, following Diamond and Dybvig (1983), we assume that all the surplus created by banks is accrued to depositors, whereas banks may charge depositors for the intermediation services and exert market power over depositors in practice. Thus, we further calculate an adjusted version of bank LPI that subtracts asset returns not accrued to depositors, including net income and non-interest expense. Second, the above LPI formula is derived in a model without deposit insurance. In Internet Appendix A, we show that the procedure to calculate the LPI for bank deposits remains the same in the presence of deposit insurance. That is, deposit insurance does not affect the validity of the LPI construction per se. A separate question is how much liquidity banks would have provided in the absence of deposit insurance. We further address this question by projecting the LPI for a hypothetical zero deposit insurance bank using the cross-sectional variation in LPI and deposit insurance. We present the results of all these alternative specifications in Section 4.3.

3.3 Data

We use bank call reports and mutual fund holdings from the CRSP database to obtain the composition of assets w_j for banks and funds, respectively.[15] We remove exchange-traded funds and index funds to obtain a sample of actively-managed open-end fixed-income funds. Table 1 provides summary statistics of the portfolio holdings of banks and funds in our sample.

For liquidation cost ϕ_j, we use collateral haircuts in repo markets and discounts on loan sales in secondary markets similar to Bai, Krishnamurthy and Weymuller (2018). Specifically, we collect securities haircuts from the New York Fed's repo data series, commercial loan haircuts from the Loan Syndications and Trading Association, and real estate loan haircuts from the Federal Home Loan Banks. We then smooth the haircut series using principal components to remove outliers.[16] Figure A1 in the Internet Appendix plots the haircut series for different asset categories over our sample period. As expected, more liquid assets such as Treasuries have smaller haircuts, whereas relatively illiquid assets such as loans have higher haircuts.

Relatedly, haircuts for different asset classes are taken as the median market haircuts in our baseline estimates. Nevertheless, there may be price impact in the sense of larger asset sales incurring larger discounts. To this end, we further allow liquidation costs to vary with outflows. Specifically, we observe the distribution of the haircuts in the data at each point in time. We assign haircuts from the distribution to each fund depending on the size of their outflows, where funds with larger outflows are assigned steeper haircuts. Internet Appendix B provides further details.

Economically, asset haircuts provide a useful proxy for average liquidation costs because illiquid fixed-income assets like bonds and loans are traded over the counter through dealers and their market prices are determined by dealers' balance sheets and funding conditions. In particular, repos are often used to fund dealers' bond positions, which closely connects repo haircuts and liquidation costs in normal times (Machiavelli and Zhou, 2022). It is conceivable to use alternative measures of asset illiquidity, such as the Amihud and Roll measures, for a subset of assets whose transaction data are available. Chernenko and Sunderam (2022) also propose a

[15] Please refer to Table A1 in the Internet Appendix for a detailed mapping between balance sheet variables and our asset categories.

[16] Specifically, we first extract the first principal component PC_t based on the panel of haircuts. Then, we regress each raw haircut time series on PC_t and use the predicted value of the regression as the smoothed haircut.

revealed preference approach to measure corporate bond illiquidity. We currently do not pursue these approaches because we would not be able to construct LPIs that are consistent across various institutions with different asset types due to the unavailability of data.

Regarding outflows λ, we calculate uninsured deposit outflows as a percentage change in total uninsured deposits using bank call reports. We augment the resulting outflow distribution with data on bank failures, where the outflow is set to 100% when a bank defaults. For each mutual fund, outflows are calculated using its portfolio-level total net asset changes using the CRSP database. For positive flows, we assume that outflows are zero. We use net outflows rather than gross redemptions because it is net outflows that result in asset liquidations, depress contract payments, and ultimately affect liquidity provision per dollar (as in Definition 2), consistent with our focus. Gross redemptions would be more relevant for considering flow netting at the fund level, as Chernenko and Doan (2022) suggest.

Taken together, we construct the realized LPI for each intermediary i in each quarter, as in equation (2.5), using their quarterly asset composition and outflows. We use the realized LPI to compare how liquidity provision for a given intermediary changes over time. We also calculate the expected LPI, as in equation (2.6), by taking the sample mean of the realized LPI over a given sample period. The assumption is that investors' expectations are consistent with average realizations. We use the expected LPI to compare liquidity provision across intermediaries.

3.4 Comparison to Existing Measures of Bank Liquidity Provision

Before proceeding, we compare the LPI to the two existing measures of bank liquidity provision, which are the Berger and Bouwman (2009) (BB) measure and the Liquidity Mismatch Index (LMI) developed by Bai, Krishnamurthy and Weymuller (2018). The LPI we develop builds on and complements these two measures, which are seminal in the banking literature. The key distinction is that the LPI can also be applied to demandable-equity issuing intermediaries like mutual funds with and without swing pricing and money market funds. This is achieved through formalizing the effect of contract design and incorporating endogenous variation in investor flows in quantifying liquidity provision.

The BB measure provides an intuitive classification of bank assets and liabilities as liquid, semi-liquid, or illiquid, assigns simple fixed weights for each category, and then measures how many illiquid assets are transformed into liquid liabilities. Rewriting the formulation in Berger and Bouwman (2009), we can express bank liquidity creation for a bank at time t with asset weights w_{jt}^A and liability weights w_{kt}^L as

$$BB_t = \left(\frac{1}{2} \sum_{k \in L} w_{kt}^L - \frac{1}{2} \sum_{k \in IL} w_{kt}^L \right) - \left(\frac{1}{2} \sum_{j \in L} w_{jt}^A - \frac{1}{2} \sum_{j \in IL} w_{jt}^A \right), \tag{3.6}$$

where illiquid assets and liabilities, $j \in IL$, take on a fixed weight of 0.5 and liquid assets and liabilities, $j \in L$, take on a fixed weight of -0.5.[17] In other words, a bank creating more liquid deposits from illiquid assets creates more liquidity.

The LMI improves on the BB by incorporating time-varying and market-based asset-side weights to capture how much liquidity the intermediary can raise at short notice in a stress scenario. This allows the LMI to more realistically link bank liquidity mismatch to market conditions. On the liability side, all claimants of the bank are assumed to extract the maximum liquidity possible given their type. The LMI is then the shortfall of liquidity that the bank raises from its assets relative to the funds that depositors demand. Rewriting the formulation in Bai, Krishnamurthy and Weymuller (2018), we can express the LMI for a bank at time t with asset weights w_{jt}^A and liability weights w_{kt}^L as

$$LMI_t = \sum_{j=0}^{J} w_{jt}^A (1 - \phi_{jt}) - \sum_{k=0}^{K} w_{kt}^L (m_{kt}), \tag{3.7}$$

where ϕ_j is the discount of asset j at time t when converted into cash at short notice,[18] and $w_{kt}^L(m_{kt})$ is a liquidity weight for each liability category k determined by general funding conditions and a fixed weight by liability type, which is specifically a function of maturity m_{kt}. For

[17] Note that this is a rewritten form of the original procedure to make the BB measure comparable to our LPI, without any loss of generality. We refer interested readers to Berger and Bouwman (2009) for the exact procedure.

[18] For simplicity and easier comparison to our LPI, we express the LMI using portfolio weights for a per dollar notion without any loss of generality. The portfolio weights can be simply multiplied by the total asset value to capture the total LMI. We refer interested readers to Bai, Krishnamurthy and Weymuller (2018) for the exact procedure to construct the LMI in the data.

example, the fixed weights for shorter-maturity deposits are effectively higher and contribute to a higher liquidity shortfall.

While the measures of BB and LMI are specifically designed for banks, the LPI can be applied to both banks and demandable equity-issuing non-banks. This is achieved by explicitly modeling contract design and incorporating empirically observed flows at the fund level rather than assuming fixed liquidity weights by liability type. As shown in Lemma 1 and Proposition 1, different contracts imply different flows in equilibrium, and how much liquidity is provided for an investor depends on her redemption value. Her redemption value in turn depends on other agents' equilibrium redemption activities, that is, flows. Therefore, contract design and the associated flows are both necessary to compare the amount of liquidity provision by debt- and equity-funded intermediaries in equilibrium.

The LPI framework is also uniquely suited to capture the effect of swing pricing. Without swing pricing, investors' redemption value only depends on the underlying fundamentals unless flows are large enough to trigger a default. When swing pricing is adopted, investors' redemption value continuously declines as outflows grow because outflows induce liquidation costs. This is why liquidity provision continuously declines with fund outflows. This analysis of how swing pricing affects liquidity provision would not have been feasible by directly using the BB or LMI measure without modeling the inter-dependence of values and outflows under different contracts.

Finally, we note that the LPI is aimed at quantifying actual liquidity provided at a point in time or expected across a period of time under different contractual forms. This focus is consistent with our use of observed flows in the data. Bai, Krishnamurthy and Weymuller (2018) focus on capturing the hypothetical liquidity shortfall at banks under stress scenarios, which is aligned with their use of liability weights reflecting depositors' maximum withdrawal of funds. Bai, Krishnamurthy and Weymuller (2018) also develop a dynamic framework, which has the advantage of incorporating the liability structure of debt in understanding liquidity mismatch in a worst-case scenario. We currently abstract away from the dynamics of the maturity structure because they are less relevant for equity contracts. Nevertheless, it would be interesting to consider a dynamic extension of our framework in future research.

4 Empirical Results

We present our empirical results. We first examine fund LPI without swing pricing in Section 4.1 and then report the counterfactual fund LPI with swing pricing in Section 4.2. Section 4.3 presents bank LPI in comparison to fund LPI. Finally, we apply the LPI to MMFs in Section 4.4.

4.1 Fund LPI without Swing Pricing

We begin with analyzing liquidity provision in the cross-section of funds. We follow the procedure described in Section 3.2.1 to construct LPIs for the funds in our sample using quarterly data. We then average at the fund level to obtain expected fund-level LPIs over our sample period. Figure 3 plots the distribution of fund LPIs and Panel (a) of Table 2 provides summary statistics. Liquidity provision by the average fund is 5.08 cents per dollar, while funds at the first, second, and third quartile of the distribution provide 4.67, 5.11, and 5.90 cents of liquidity per dollar. In other words, investors receive 5.08% more liquidity from the average fund than they would have received without the fund, and they receive 4.67%, 5.11%, and 5.90% more liquidity from funds at the first, second, and third quartile of the distribution than they would have received on their own. These estimates are based on a fund equity contract whose value is insensitive to fund outflows.

One concern is that funds may expect some outflows so that the observed outflows and portfolio assets correspond to funds that partially strike their NAVs in reality. Hence, we recompute fund LPIs allowing the contract payment to partially respond to fund outflows, as explained in Section 2.4 and Appendix B.4. Panel (a) of Table 2 also shows the results for fund LPI with different degrees of NAV striking. Overall, fund LPIs remain similar with the average ranging between 5.00 to 5.08 cents per dollar. Within this range, fund LPIs are lower when the degree of NAV striking is larger. Intuitively, given the observed outflows and asset composition in the data, contract payments are lower when NAVs are more sensitive to outflows.

Another concern is that the effective liquidity received by investors is lower as a result of fund management fees. To this end, we repeat our calculation of fund LPI by subtracting management fees from each fund's contract payment. Panel (a) of Table 3 shows our results. Overall, the average fund LPI slightly decreases from 5.08 cents per dollar to 4.81 cents per dollar. Thus, bond mutual funds provide a significant amount of liquidity even net of fees.

Finally, we repeat our estimates with outflow-adjusted haircuts by assigning haircuts from the distribution to each fund depending on the size of its outflows.[19] The result presented in Table 4 shows that our estimates remain similar in magnitude.

4.2 Fund LPI with Swing Pricing

We then calculate the counterfactual fund LPIs with swing pricing. Recall from Propositions 1, 2, and the LPI construction in Section 3.2.2 that swing pricing involves several adjustments to the calculation of fund LPI. First, the contract payment becomes fully responsive to outflows, which decreases the LPI, all else equal. At the same time, funds hold less cash and more illiquid assets and benefit from dampened outflows because investors' run incentive is reduced. A higher fraction of illiquid assets and dampened outflows should both increase the LPI, all else equal. Hence, the direction and magnitude of the effect of swing pricing on fund liquidity provision remain an empirical question.

In Figure 4, we plot the percentage change in average fund-level LPI with the adoption of swing pricing. We find that 67% of funds experience an increase in average LPI with a large dispersion in magnitude. Only 33% of funds experience a net drop in LPI with swing pricing. Overall, with the adoption of swing pricing, the average fund LPI is 5.42 cents per dollar (Panel (b) of Table 2), which corresponds to a 6.7% increase relative to the fund LPI without swing pricing. The first three quartiles of fund LPIs are also higher with swing pricing, at 4.96, 5.25, and 6.04 cents per dollar, respectively. Repeating the calculation by subtracting management fees from each fund's contract payment, we also find an increase in fund LPI from 4.81 cents to 5.12 cents per dollar (Panel (b) of Table 3). Taken together, our results suggest that the adoption of swing pricing would enhance rather than constrain the capacity for liquidity provision on average for the sample of U.S. fixed-income mutual funds that we study.

[19] See Appendix B for more details.

The adoption of swing pricing may also influence the characteristics of fund liquidity provision. To better understand the variation in liquidity provision across funds, we regress the average LPI for fund j against its average outflow, the ratio of cash over total assets, the average illiquidity of non-cash assets, and several additional fund-level controls. That is,

$$LPI_j = \alpha + \beta_1 Outflow_j + \beta_2 CashRatio_j + \beta_3 AssetIlliquidity_j + Controls_j + \epsilon_j, \tag{4.1}$$

where $Controls_j$ includes log asset size, log fund age, an indicator variable for retail funds, and fund expense ratio. We estimate the results for fund LPI with and without swing pricing and show the results in Table 5.[20]

From Table 5, we find that higher fund LPI is associated with smaller outflows, lower cash ratios, and more illiquid assets, all else equal. The results also show that swing pricing renders fund LPI more sensitive to outflows. A 10% smaller average outflow corresponds to a 0.096 cents per dollar higher LPI without swing pricing and a 0.508 cents per dollar higher LPI with swing pricing. This difference arises because swing pricing requires contract payment to fully internalize the cost of outflows so that outflows directly lead to drops in liquidity provision. At the same time, it is precisely because the contract payment adjusts with outflows that investors' run incentives are reduced and thus funds can hold lower cash buffers and more illiquid assets, as shown in Proposition 2. Consistent with swing pricing allowing for a larger proportion of illiquid asset holdings without inducing panic runs, we find that swing pricing amplifies the effect of asset illiquidity on fund LPI. When the average illiquidity of a fund's non-cash assets increases by one standard deviation, the LPI without swing pricing increases by $0.906 \times 0.842 = 0.763$ cents per dollar while the LPI with swing pricing increases by $1.032 \times 0.842 = 0.86$ cents per dollar.

4.3 Fund LPI versus Bank LPI

To provide a benchmark for understanding the extent of fund liquidity provision, we also calculate the cross-section of bank LPIs. Similar to funds, we follow the procedure in Section 3.2.3 and

[20] In theory, funds' asset type, cash holdings, and investors' outflows are jointly determined in equilibrium so this exercise presents a correlation rather than causation between fund characteristics and the LPI.

then average over time at the bank level. The cross-sectional distribution of bank LPIs is shown in Panel (a) of Figure 5. In the overall sample period, a dollar invested in the average bank provides 27.47 cents per dollar of liquidity (panel (c) of Table 2). In comparison, funds provide a significant amount of liquidity per dollar at 5.08/27.47=18.5% of that of banks. As a robustness check, we also calculate bank LPI using lagged asset values for the expected portfolio value, as explained in subsection 3.2.3. The bank LPI remains very similar at an average of 26.72 cents per dollar.

One concern could be that the bank LPI in our comparison is mechanically inflated by deposit insurance and non-deposit liabilities that only banks have access to. Although our LPI formula considers the uninsured portion of bank deposits, deposit insurance and non-deposit liabilities may indirectly affect the LPI magnitude through banks' run risk and portfolio choice. Unfortunately, the ideal experiment of the same bank operating with and without deposit insurance does not exist. Thus, we perform a simple test in this section to show that regulation does not explain away the liquidity provision by debt-funded intermediaries.

Our first test relates bank-level LPIs to the ratio of insured deposits in the data and projects the LPI that would have applied to a hypothetical bank without insured deposits. To this end, we regress the average LPI for bank j against its ratio of insured deposits and non-deposit liabilities. That is,

$$LPI_j = \alpha + \beta_1 InsuredDepRatio_j + \beta_2 NonDepLiab_j + \epsilon_j. \tag{4.2}$$

Then, the constant term can be interpreted as the hypothetical bank LPI if the ratio of insured deposits and non-deposit liabilities were zero. Our second test makes use of the 2016 Money Market Reform and is explained in the next section.

From columns (1) and (2) of Table 6, we see that the constant terms are positive and statistically significant at the 1% level. Magnitude-wise, the projected average bank LPI without insured deposits would be 20.91 cents per dollar while the projected average bank LPI without insured deposits and other types of non-deposit funding would further drop to 19.42 cents per dollar. These LPIs are below the average observed bank LPIs and they suggest an even smaller gap in liquidity provision between banks and fixed-income mutual funds absent the protection from deposit insurance and non-deposit funding for banks.

Columns (3) and (4) of Table 6 repeat the estimation including several additional bank characteristics.[21] The results show that banks with more deposit insurance, more non-deposit liabilities, and a larger asset size tend to provide more liquidity. Banks' default risk and their asset choices are jointly determined in equilibrium, but all else equal, banks with more illiquid portfolios, lower cash buffers and lower default risk also have higher LPIs.

Another concern is that bank market power may reduce the actual amount of liquidity that depositors receive, similar to how management fees reduce fund LPI. Hence, we recompute bank LPI by subtracting proceeds that are not accrued to depositors, including net income and non-interest expense, from the bank's contract payment. Our results show that the resulting LPI decreases from an average of 27.47 cents per dollar to 26.26, as presented in panel (c) of Table 3.

Finally, we examine realized fund versus bank liquidity provision over time and find that the gap has been narrowing. In panel (b) of Figure 5, we plot the distribution of bank LPIs in 2011 and 2017. We observe that the distribution of realized bank LPIs shifts markedly to the left from 2011 to 2017. Echoing this shift in the distribution, the liquidity provided by the average dollar in banks and funds has been converging towards each other in a value-weighted sense. In Figure 6, we plot the quarterly average of bank- and fund-level LPIs from 2011Q1 to 2017Q4 weighted by asset size. From the figure, we observe that from 2011Q1 to 2017Q4, liquidity provided by each dollar in bank deposits has decreased from 32.4 to 23.3 cents per dollar, while liquidity provided by each dollar in fund shares has increased from 4.9 to 5.2 cents per dollar. In other words, within six years, the liquidity provided by an average dollar invested in funds has increased from about one-eight to one-fifth of a dollar invested in commercial banks.

While a full characterization of the narrowing in realized fund versus bank LPI is beyond the scope of this paper, we highlight the important role played by unconventional monetary policy and changes in bank regulation.

We first consider the increase in central bank reserves following Quantitative Easing (QE). Excess reserves held with the Federal Reserve are liquid assets on bank balance sheets. The overall effect of more reserves on liquidity provision can go in two different ways. It could have a positive effect because more liquid bank balance sheets are less prone to runs. On the other

[21] We demean these variables to maintain consistency in the size of the constant terms.

hand, a portfolio with more reserves also decreases the potential for liquidity provision by the intermediary.

Empirically, we find evidence consistent with the latter effect being dominant, i.e., QE decreases the capacity of liquidity provision by banks. As shown in Panel (a) of Figure 7, the expansion in excess reserves from $1 trillion in 2011Q3 to more than $2.5 trillion in 2014Q3 is mirrored by a corresponding sharp fall in bank LPI during the same period. Sorting banks into quartiles of reserve uptake as a proportion of balance sheet size, we observe that the LPI drops consistently more for banks with higher reserve uptake. Intuitively, this is because banks' liquidity transformation for liquid reserves is very limited.

In this context, the implementation of the Liquidity Coverage Ratio (LCR) had similar effects on bank liquidity provision. In the U.S., the LCR stipulates that banks with $250 billion or more in total assets or $10 billion or more in on-balance sheet foreign exposures are required to hold sufficient amounts of High Quality Liquid Assets (HQLA), which include cash, central bank reserves, and some agency MBS, to cover expected net cash outflows for a 30-day stress period. Banks with $50 billion or more in consolidated assets are also subject to a less stringent LCR requirement. Similar to the QE case, the LCR requires large banks to hold a higher fraction of liquid assets on their balance sheets, which raises the default threshold in terms of outflows but also increases the liquidation value of the benchmark asset portfolio.

We find evidence for an overall negative impact of the LCR requirement on bank liquidity provision within our sample period. Panel (b) of Figure 7 shows that banks most impacted by the LCR, i.e., above $250 billion in total assets, also experience the most pronounced decline in LPI relative to those without and with a less stringent LCR requirement. This is again consistent with the interpretation that the LCR moves commercial banks more towards a narrow-banking business model, which constrained bank liquidity provision and may have contributed towards the migration of liquidity provision to funds.

4.4 Application: MMF LPI and the Money Market Reform

We further apply our LPI to shed light on liquidity provision by MMFs. This is in itself an important question given the essential role of MMFs as a source of liquid assets for retail investors and a lender to financial institutions. At the same time, MMFs during our sample also help to inform the capacity of debt versus equity in liquidity provision. In October 2016, the SEC implemented the Money Market Reform. Among other changes, institutional prime and tax-exempt MMFs were required to switch from reporting a $1 fixed share price to a floating NAV, which effectively corresponds to a switch from demandable debt to demandable equity in our framework. Importantly, only the floating NAV rule did not apply to retail prime funds who continued reporting a $1 fixed share price.[22] This setting naturally lends itself to a difference-in-differences analysis to study liquidity provision by debt- and equity-funded intermediaries with institutional and retail prime MMFs as treatment and control groups, respectively.

Panel (a) of Figure 8 shows the ratio of cash holdings for retail and institutional prime and tax-exempt MMFs. We observe that the proportion of cash started to increase about a year before the October 2016 implementation date, which is indicated by the dotted line, and then declined after the reform, settling around pre-reform levels around the beginning of 2018. This trend is likely because leading up to the reform, institutional MMFs converted more assets into cash anticipating the need of meeting heightened redemptions. Heightened redemptions were likely anticipated as the reform has been discussed and announced before the implementation date. Following the reform, cash declined as it was increasingly used up by investor redemptions that remained elevated for some time after the reform.

While the developments right around the implementation of the reform are interesting, they may reflect temporary adjustments rather than fundamental changes in outflow distribution and asset composition. Since our goal is to compare equilibrium liquidity provision by debt- versus equity-funded MMFs, we end our pre-period before anticipation effects begin in October 2015, one year before the implementation date, and start our post-period after outflows and cash ratios have stabilized in January 2018.

In Panel (b) of Figure 8, we plot the average LPI of retail versus institutional MMFs from January 2014 to September 2019. The first and second solid lines indicate the end of the pre-period in October 2015 and the start of the post-period in January 2018, respectively. There are large swings in MMF LPI around the implementation, but the LPI of retail and institutional

[22] Other regulations introduced in the 2016 Money Market Reform include liquidity fees and gates, which apply to all MMFs. See "Money Market Fund Reform; Amendments to Form PF." https://www.sec.gov/rules/final/2014/33-9616.pdf

funds were generally parallel to each other in the pre-period. In the post-period, the LPI of institutional MMFs experienced a larger drop than retail funds but remains positive throughout. This pattern provides evidence consistent with demandable equity providing less but significant amounts of liquidity compared to demandable debt.

More formally, we conduct a difference-in-differences test with institutional funds making up the treatment group and retail funds making up the control group. The treatment is then the post-reform period. Specifically, for MMF LPIs from January 2014 to September 2019, we estimate

$$LPI_{jt} = \alpha + \beta_1 PostReform_t + \beta_2 InstitutionalFund_j + \beta_3 PostReform_t * InstitutionalFund_j + \epsilon_{jt}. \tag{4.3}$$

Column (1) of Table 7 shows the results for the baseline. The coefficient on the interaction term is negative and significant at the 1% level, which suggests that changing from debt to equity lowers liquidity provision. Nevertheless, institutional MMFs still preserve 1-0.23/(3.97-0.26)=93.8% of their liquidity provision as they switch from fixed to floating NAVs. To ensure that fund openings and closures are not dominating our results, column (2) shows the results using the subsample of funds appearing in both the pre- and post-reform periods. We further provide robustness checks for the time windows chosen. Column (3) shows the results with an earlier end of the pre-period in July 2015, and column (4) shows the results with a later start of the post-period in June 2018. The coefficient on the interaction term remains negative and significant in all three cases. Their economic magnitudes are also similar to the baseline model with institutional MMFs retaining 91.4% to 93.3% of their LPIs.

Our results in this section suggest that for institutional MMFs, demandable equity provides a significant amount of liquidity. Our results in Section 4.2 suggest that MMF liquidity provision may be further enhanced if fund equity were to incorporate swing pricing. Indeed, swing pricing for MMFs was among the policy changes announced for MMFs following the Covid-19 crisis. Quantifying the effect of swing pricing on MMF LPI may be a promising avenue for future research once sufficient data following the implementation becomes available.

5 Conclusion

This paper demonstrates that demandable equity issued by non-bank intermediaries is able to provide liquidity just like demandable debt issued by the traditional banking sector. Liquidity provision stems from the pooling of idiosyncratic liquidity shocks at the intermediary level, which occurs independently of the contractual form of the intermediary's liabilities as long as they are redeemable at short notice.

Based on the theory, we develop the Liquidity Provision Index (LPI) as a parsimonious measure of liquidity provision across different types of intermediaries. It captures the extra proceeds an investor expects to obtain by withdrawing a debt or equity claim from an intermediary relative to directly holding and selling the underlying portfolio of assets herself. Our LPI measure shows that the average bond mutual fund provides 5.08 cents of liquidity per dollar, which is economically significant at around one-fifth of that by bank deposits. Surprisingly, fund liquidity provision could be further improved by 6.7% if swing pricing was adopted. This is because swing pricing reduces the need of holding liquid asset buffers to meet large redemption requests, which allows a larger amount of illiquid assets to be held to maturity.

The migration of liquidity provision away from deposit-issuing banks to equity-issuing financial institutions bears far-reaching implications. This was evident during the Covid-19 crisis when bond funds suffered heightened outflows, collectively liquidated their portfolios, and induced strains in Treasury and corporate bond markets (Falato, Goldstein and Hortacsu, 2021, Ma, Xiao and Zeng, 2021). Going forward, our model predicts that the adoption of swing pricing for mutual funds is uniquely suited to allow for liquidity provision without triggering large-scale panic-driven runs. Swing pricing would also improve the capacity of funds to transform liquidity.

Figure 1: Size of the US Fixed-Income Mutual Fund Sector

The upper panel plots the total asset size of U.S. fixed-income mutual funds from January 1995 to December 2019. Fixed-income funds include government bond funds, corporate bond funds, loan funds, and multi-sector bond funds. The lower panel plots the ratio of fund shares relative to bank deposits in the same sample period. Data source: Morningstar and Flow of Funds.

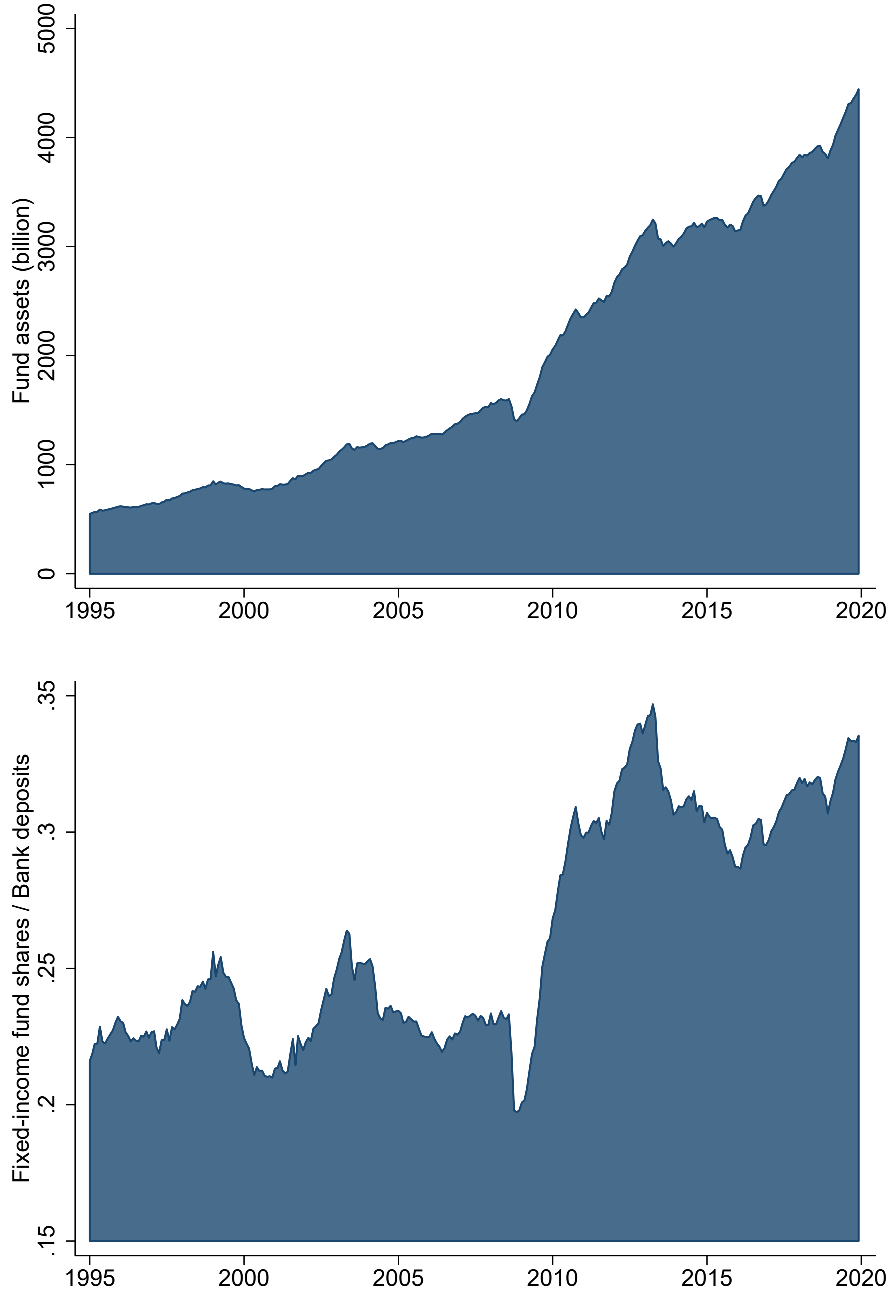


Figure 2: LPI for Fund Equity with and without Swing Pricing

This graph depicts the level of LPIs against outflows λ. The solid line represents the LPI for fund equity with swing pricing, in which case fund NAV continuously adjusts downward as more agents redeem and the fund exhausts cash and liquidates the illiquid asset. The dashed line corresponds to the LPI for fund equity without swing pricing, which features a discontinuous jump when the fund fully liquidates due to the inability to adjust its NAV to incorporate liquidation costs.

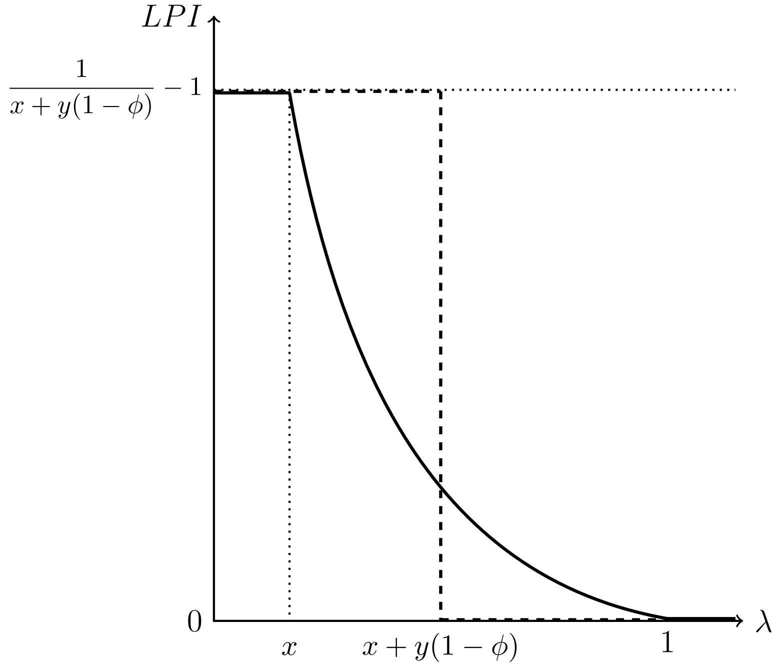


Figure 3: Fund Liquidity Provision in the Cross-section

This figure plots the cross-sectional distribution of fund-level LPI. The LPI for each fund is calculated as the average LPI over the sample period from 2011 to 2017. The distribution is truncated at 0.08, where observations in the tail are assigned to the last bin.

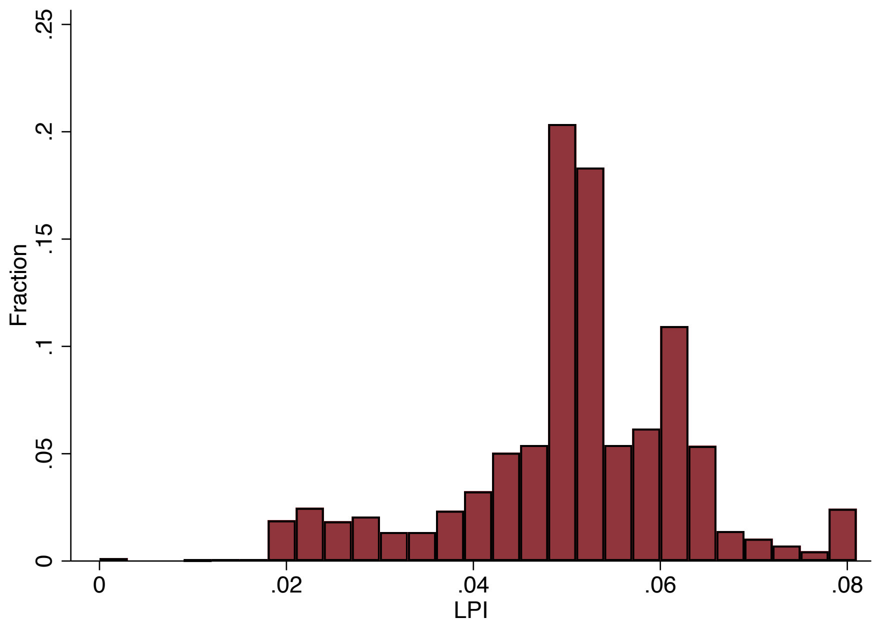


Figure 4: The Effect of Swing Pricing on Fund Liquidity Provision

This figure plots the percentage change in LPI if swing pricing is implemented. The LPI without swing pricing is the observed LPI for each fund averaged over the sample period from 2011 to 2017. The LPI with swing pricing follows the adjustment in Section 3.2.2. The distribution is truncated at 100%, where observations in the tail are assigned to the last bin.

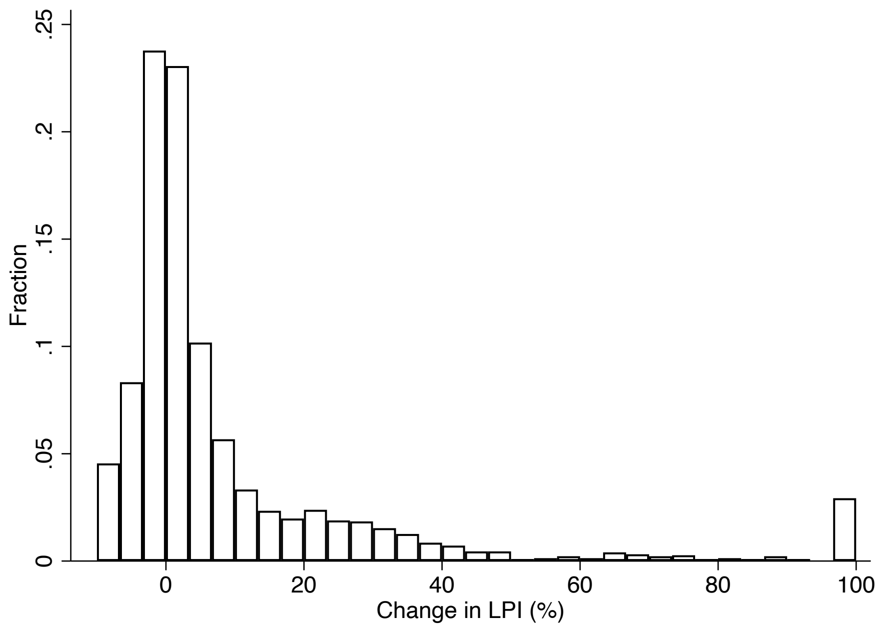
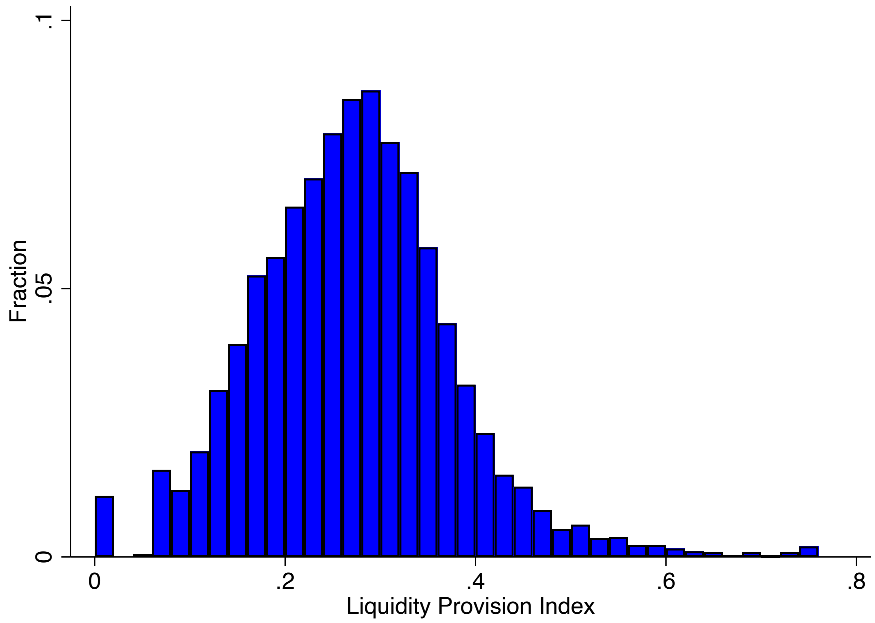


Figure 5: Bank Liquidity Provision in the Cross-section

The upper panel plots the cross-sectional distribution of bank-level LPI, where the LPI for each fund is calculated as the average LPI over the sample period from 2011 to 2017. The lower panel plots the cross-sectional distribution of bank-level LPI, where the LPI for each fund is calculated as the average LPI in 2011 and 2017, respectively.

(a) Overall Bank LPI



(b) Bank LPI in 2011 and 2017

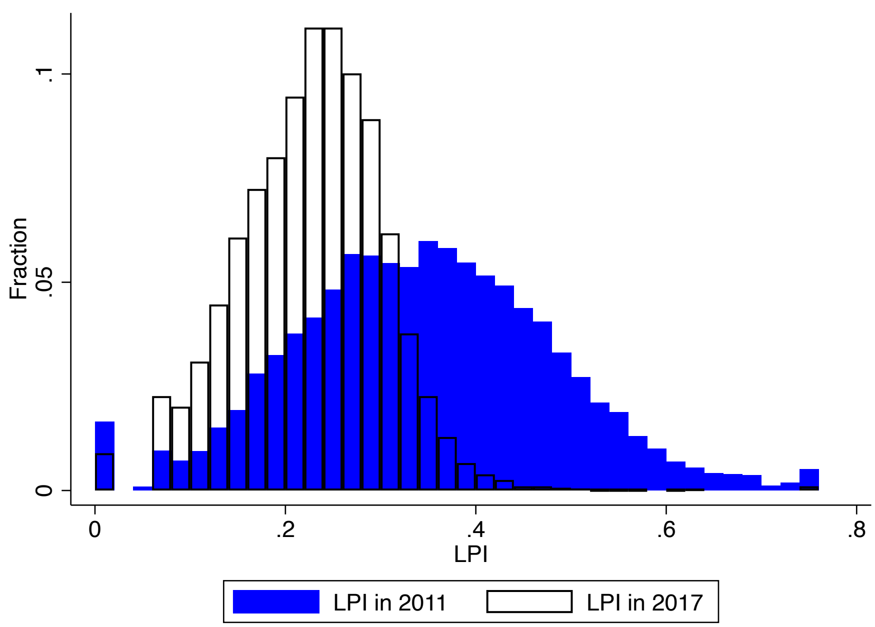


Figure 6: Bank and Fund Liquidity Provision over Time

This figure plots the weighted average LPI for commercial banks and bond mutual funds from 2011 to 2017. We first calculate the LPI for each bank and fund in each quarter and then plot the asset-size-weighted average LPI from 2011 to 2017.

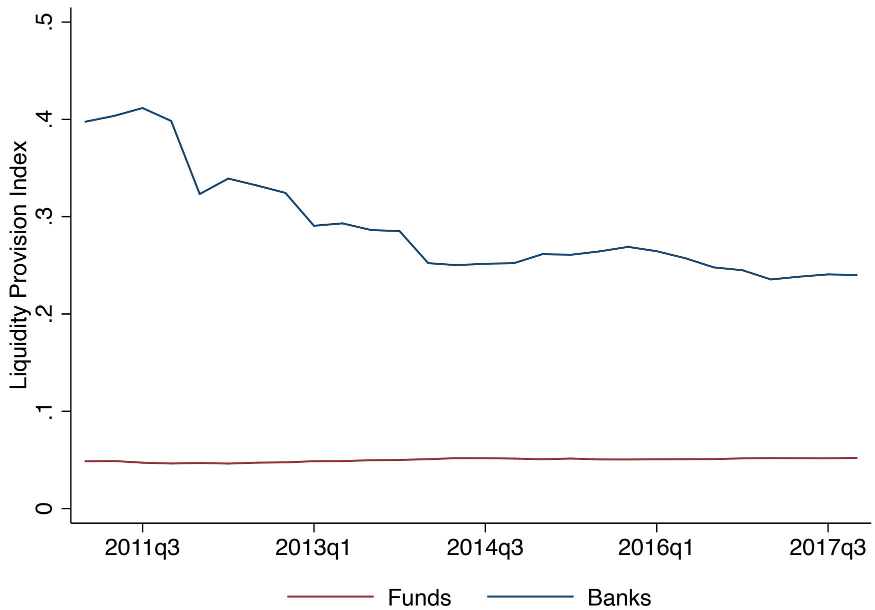
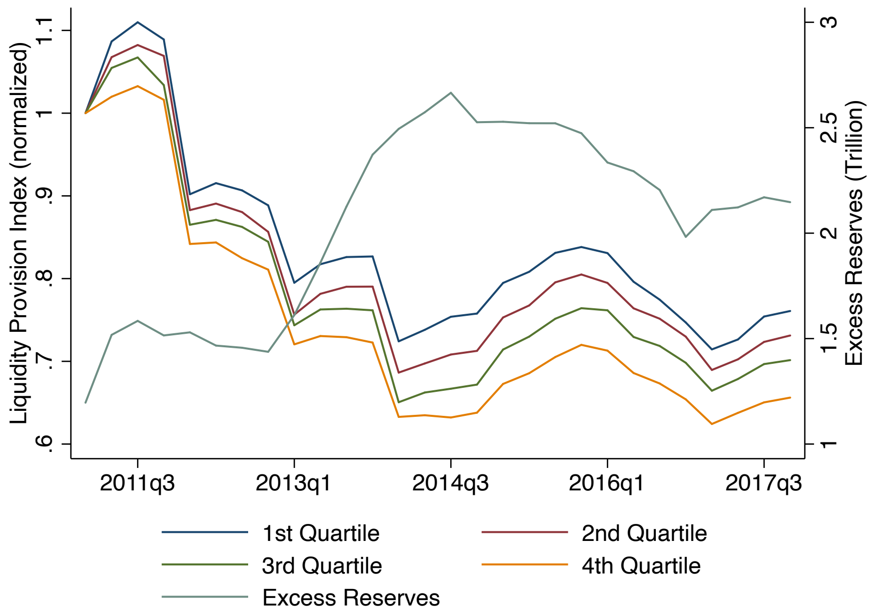


Figure 7: Bank Liquidity Provision, Excess Reserves, and Liquidity Regulation

Panel (a) plots the LPI for banks by reserve uptake quartile (left axis) and the aggregate volume of excess reserves (right axis) from 2011 to 2017. Reserve uptake is measured as the change in reserves as a fraction of total assets from 2011Q1 to 2014Q3, when reserve levels peak. We plot the median LPI in each quartile normalized by its initial value in 2011Q1. Panel (b) plots the LPI for commercial banks by asset size groups for the Liquidity Coverage Ratio. Banks are sorted by asset size into those above $250 billion, between $50 and $250 billion, and below $50 billion. We plot the median LPI in each asset group normalized by its initial value in 2011Q1.

(a) Bank Liquidity Provision and Excess Reserves



(b) Bank Liquidity Provision and the Liquidity Coverage Ratio

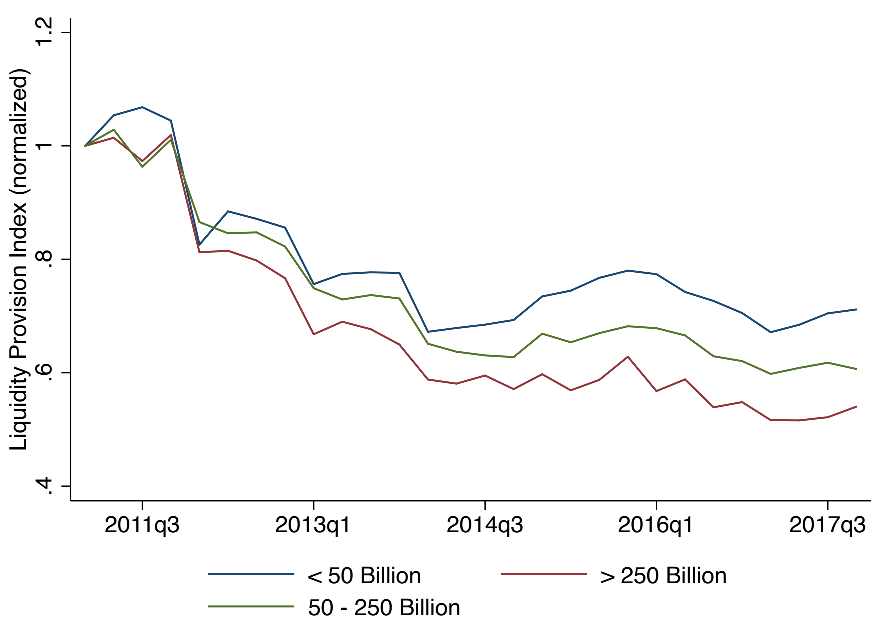
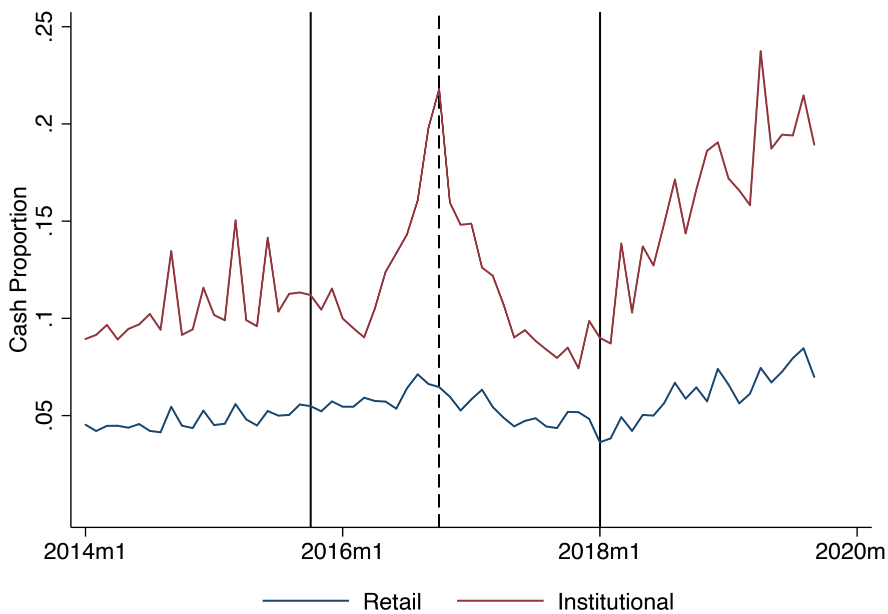


Figure 8: MMF Liquidity Provision

The upper panel plots the average proportion of cash holdings of institutional and retail prime and tax-exempt MMFs from January 2014 to September 2019. The lower panel plots the average LPIs of institutional and retail prime and tax-exempt MMFs from January 2014 to September 2019. The dotted line marks the implementation of the Money Market Reform in October 2016. The two solid lines correspond to the start and end of the reform period, October 2015 and January 2018, respectively.

(a) Cash in MMF Holdings



(b) Liquidity Provision Index

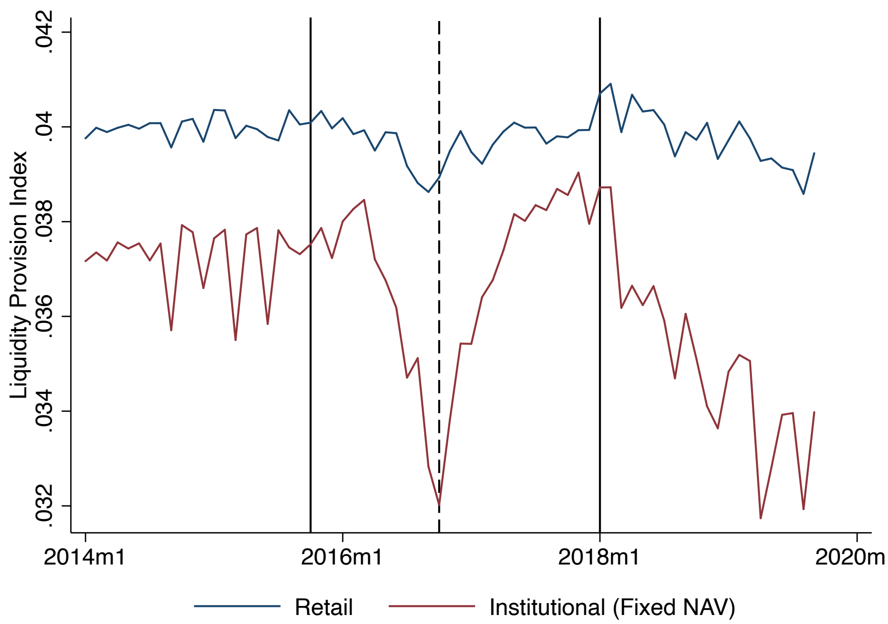


Table 1: Summary Statistics

This table provides summary statistics of the assets and liabilities of banks and fixed-income funds. We report moments of the cross-sectional distribution after averaging each variable at the fund or bank level.

(a) Funds

	mean	sd	p25	p50	p75
Cash	3.47	6.29	0.75	1.91	3.76
Treasuries	12.32	20.34	0.00	1.33	18.22
Agency Debentures	2.76	8.93	0.00	0.00	1.01
Agency MBS/CMO	5.76	12.19	0.00	0.00	5.03
Money Market	0.93	3.86	0.00	0.02	0.56
Muni	29.28	43.84	0.00	0.56	94.08
Corporate Bonds	32.02	32.97	0.01	26.30	57.46
CMO/ABS	5.56	10.02	0.00	0.23	7.61
Equities	7.53	18.54	0.07	1.80	5.53
Outflow	0.03	0.04	0.01	0.02	0.04

(b) Banks

	mean	sd	p25	p50	p75
Cash	11.66	9.62	5.63	9.10	14.58
Treasuries	0.62	2.59	0.00	0.00	0.17
Agency Debentures	5.73	7.44	0.75	3.18	7.81
Agency MBS/CMO	8.06	9.51	0.75	5.23	11.75
Money Market	0.00	0.00	0.00	0.00	0.00
Muni	6.29	7.83	0.45	3.47	9.46
Corporate Bonds	0.63	2.16	0.00	0.00	0.34
CMO/ABS	0.31	1.63	0.00	0.00	0.01
Equities	0.20	1.92	0.00	0.00	0.00
Commercial Loans	12.69	10.30	5.46	10.24	17.43
Consumer Loans	3.26	5.86	0.74	1.88	3.81
Real Estate (Family Housing)	19.00	14.35	8.85	15.86	25.09
Real Estate (Other)	25.98	14.02	15.52	25.55	35.48

Table 2: Fund and Bank LPI

This table provides summary statistics of the LPI for funds and banks. We report moments of the cross-sectional distribution after averaging LPI at the fund or bank level. Panel (a) shows the fund LPI and fund LPIs for different degrees of NAV striking but without swing pricing adjustments. Panel (b) shows fund LPI with swing pricing adjustments to outflows and assets. Panel (c) shows bank LPI.

(a) Funds

	mean	sd	p25	p50	p75
LPI	5.08	1.23	4.67	5.11	5.90
LPI (10% NAV Striking)	5.07	1.23	4.67	5.10	5.89
LPI (20% NAV Striking)	5.07	1.23	4.66	5.09	5.88
LPI (30% NAV Striking)	5.06	1.22	4.65	5.08	5.86
LPI (40% NAV Striking)	5.05	1.22	4.64	5.07	5.85
LPI (50% NAV Striking)	5.04	1.22	4.63	5.07	5.84
LPI (60% NAV Striking)	5.03	1.22	4.63	5.06	5.84
LPI (70% NAV Striking)	5.02	1.22	4.62	5.05	5.82
LPI (80% NAV Striking)	5.01	1.22	4.61	5.04	5.82
LPI (90% NAV Striking)	5.00	1.22	4.60	5.04	5.81

(b) Funds with Swing Pricing

	mean	sd	p25	p50	p75
LPI (Swing Pricing)	5.42	1.07	4.96	5.25	6.04

(c) Banks

	mean	sd	p25	p50	p75
LPI	27.47	10.20	20.55	27.20	33.34

Table 3: Fund and Bank LPI (Net)

This table provides summary statistics of the LPI for funds and banks net of fees and expenses. We report moments of the cross-sectional distribution after averaging LPI at the fund or bank level. We deduct management fees for funds and net income and non-interest expenses for banks. Panel (a) shows the fund LPI and fund LPIs for different degrees of NAV striking but without swing pricing adjustments. Panel (b) shows fund LPI with swing pricing adjustments to outflows and assets. Panel (c) shows bank LPI.

(a) Funds

	mean	sd	p25	p50	p75
LPI	4.81	1.42	4.40	4.71	5.49
LPI (10% NAV Striking)	4.81	1.41	4.39	4.70	5.48
LPI (20% NAV Striking)	4.80	1.41	4.38	4.69	5.48
LPI (30% NAV Striking)	4.79	1.41	4.36	4.68	5.46
LPI (40% NAV Striking)	4.78	1.41	4.35	4.66	5.45
LPI (50% NAV Striking)	4.77	1.41	4.35	4.65	5.45
LPI (60% NAV Striking)	4.76	1.41	4.34	4.64	5.43
LPI (70% NAV Striking)	4.75	1.41	4.33	4.63	5.43
LPI (80% NAV Striking)	4.74	1.41	4.32	4.62	5.42
LPI (90% NAV Striking)	4.73	1.41	4.31	4.61	5.41

(b) Funds with Swing Pricing

	mean	sd	p25	p50	p75
LPI (Swing Pricing)	5.12	1.27	4.51	4.91	5.64

(c) Banks

	mean	sd	p25	p50	p75
LPI	26.26	10.06	19.48	25.96	31.99

Table 4: Fund and Bank LPI (Outflow-Adjusted Haircut)

This table provides summary statistics of the LPI for funds and banks with outflow-adjusted haircuts. We report moments of the cross-sectional distribution after averaging LPI at the fund or bank level. Panel (a) shows the fund LPI and fund LPIs for different degrees of NAV striking but without swing pricing adjustments. Panel (b) shows fund LPI with swing pricing adjustments to outflows and assets. Panel (c) shows bank LPI.

(a) Funds

	mean	sd	p25	p50	p75
LPI	5.32	2.15	3.98	5.08	6.38
LPI (10% NAV Striking)	5.30	2.14	3.97	5.07	6.38
LPI (20% NAV Striking)	5.29	2.13	3.96	5.07	6.37
LPI (30% NAV Striking)	5.28	2.12	3.96	5.05	6.35
LPI (40% NAV Striking)	5.26	2.12	3.95	5.04	6.34
LPI (50% NAV Striking)	5.25	2.11	3.94	5.03	6.32
LPI (60% NAV Striking)	5.24	2.10	3.94	5.03	6.31
LPI (70% NAV Striking)	5.22	2.09	3.93	5.02	6.29
LPI (80% NAV Striking)	5.21	2.09	3.92	5.02	6.27
LPI (90% NAV Striking)	5.20	2.08	3.91	5.01	6.25

(b) Funds with Swing Pricing

	mean	sd	p25	p50	p75
LPI (Swing Pricing)	5.60	1.99	4.34	5.44	6.58

(c) Banks

	mean	sd	p25	p50	p75
LPI	27.47	10.20	20.55	27.20	33.34

Table 5: Determinants of Fund LPI

This table shows the relationship between fund LPI and various fund characteristics, including the average fund outflow, the ratio of cash over total assets, average asset illiquidity, log of asset size, log of fund age, retail fund indicator, and expense ratio. Columns (1) and (2) show the results for fund LPI without swing pricing and columns (3) and (4) show the results for fund LPI with swing pricing. LPI and all explanatory variables are averaged over the sample period from 2011 to 2017.

	LPI (without Swing Pricing)		LPI (with Swing Pricing)	
	(1)	(2)	(3)	(4)
Outflow	-0.966***	-0.960***	-5.289***	-5.075***
	(0.158)	(0.175)	(0.299)	(0.327)
Cash Ratio	-0.048***	-0.048***	-0.030***	-0.031***
	(0.000)	(0.000)	(0.001)	(0.001)
Asset Illiquidity	0.915***	0.906***	1.007***	1.032***
	(0.008)	(0.010)	(0.017)	(0.019)
Asset Size		0.005		0.026***
		(0.004)		(0.008)
Age		-0.020**		0.077***
		(0.009)		(0.017)
Retail		-0.053**		-0.094**
		(0.023)		(0.046)
Expense Ratio		3.569*		4.706
		(1.942)		(3.892)
Constant	0.820***	0.803***	0.313***	-0.489***
	(0.047)	(0.090)	(0.098)	(0.179)
Observations	2,215	1,935	2,215	1,935
Adjusted R2	0.95	0.94	0.69	0.70

Table 6: Determinants of Bank LPI

This table shows the relationship between bank LPI and various bank characteristics, including the insured deposits ratio, the non-deposit liabilities ratio, the default probability, the ratio of cash over total assets, asset illiquidity, and log of asset size. Bank LPI and all explanatory variables are averaged over the sample period from 2011 to 2017. Default probability, the ratio of cash over total assets, asset illiquidity, and log of asset size are demeaned for easier interpretation of the constant term.

	LPI			
	(1)	(2)	(3)	(4)
Non-deposits Liab.	0.04**		0.06***	0.13***
	(0.02)		(0.02)	(0.01)
Insured Dep. Ratio		0.08***	0.08***	0.02***
		(0.01)	(0.01)	(0.01)
Default Prob				-0.36***
				(0.01)
Cash Ratio				-0.33***
				(0.00)
Asset Illiquidity				1.31***
				(0.01)
Asset Size				0.42***
				(0.05)
Constant	26.85***	20.91***	19.42***	23.37***
	(0.31)	(0.93)	(1.03)	(0.53)
Observations	7,551	7,551	7,551	7,537
Adjusted R2	0.00	0.01	0.01	0.79

Table 7: The Effect of Floating NAV on MMF Liquidity Provision

This table shows the effect of the 2016 Money Market Reform on liquidity provision by institutional prime funds versus retail prime funds. *Institutional Fund* is a dummy variable for the treatment group. *Post Reform* is an indicator variable for the treatment period. Column (1) shows the results for the baseline specification, where the pre-period is from January 2014 to October 2015 and the post-period is from January 2018 to October 2019. In column (2), we restrict the sample to the set of funds that appear in both the pre- and post-period. Column (3) shows the results with an earlier end of the pre-period in July 2014. Column (4) shows the results with a later start of the post-period in June 2018.

	(1) LPI	(2) LPI	(3) LPI	(4) LPI
Post Reform	-0.04	0.05	-0.06	-0.06*
	[0.03]	[0.03]	[0.04]	[0.04]
Institutional Fund	-0.26***	-0.26***	-0.26***	-0.26***
	[0.04]	[0.04]	[0.04]	[0.04]
Post Reform * Institutional Fund	-0.23***	-0.25***	-0.32***	-0.28***
	[0.06]	[0.05]	[0.06]	[0.06]
Constant	3.97***	3.97***	3.97***	3.97***
	[0.03]	[0.03]	[0.03]	[0.03]
Observations	1237	1153	1213	1234
Adj. R-squared	0.10	0.09	0.12	0.11

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A Proofs

Proof of Lemma 1. We first prove part i). Given the definition of panic runs, it suffices to provide sufficient conditions under which the two equilibria of $\lambda^* = \pi$ and $\lambda^* = 1$ co-exist for fund equity $c_f(R)$ and bank debt c_b. Consider $\pi = 0$. For notational convenience, we label the action of withdrawing/redeeming at $t = 1$ by a late agent as her action 1, and the action of staying with the intermediary until $t = 2$ as action 0. For fund equity, the payoff gain for a late agent to redeem at $t = 1$ (compared to staying until $t = 2$) when other late agents redeem is

$$\Delta(1, 1) = x + (1 - \phi)y\beta(R) - 0 > 0\,, \tag{A.1}$$

while the payoff gain for a late agent to stay until $t = 2$ (compared to redeeming at $t = 1$) when other late agents stay is

$$\Delta(0, 0) = x + yR - (x + y\beta(R)) > 0\,,$$

implying that the two equilibria of $\lambda^* = 0$ and $\lambda^* = 1$ co-exist for any R, that is, panic runs happen.

Similarly, for bank debt, the payoff gain for a late agent to withdraw at $t = 1$ when other late agents withdraw is

$$\Delta(1, 1) = x + (1 - \phi)y\beta(R) - 0 > 0\,,$$

while the payoff gain for a late agent to stay until $t = 2$ when other late agents stay is

$$\Delta(0, 0) = x + yR - c_b\,,$$

which is positive when

$$R > \frac{c_b - x}{y}\,,$$

implying that the two equilibria of $\lambda^* = 0$ and $\lambda^* = 1$ co-exist for any sufficiently large R, that is, panic runs happen.

We then prove part ii). It suffices to show that under any given parameters, asset allocations, and fundamentals, the solution of λ^* is unique for fund equity with swing pricing $c_s(R, \lambda)$.

Case 1. Consider the case of $x \geq \lambda(x + y\beta(R))$, which implies that $l = 0$, end-of-day NAV at $t = 1$ is $NAV_1(\lambda) = x + y\beta(R)$, and end-of-day NAV at $t = 2$ is

$$\begin{aligned} NAV_2(\lambda) &= \frac{x - \lambda(x + y\beta(R)) + yR}{1 - \lambda} \\ &= x + y\beta(R) + \frac{y}{1-\lambda}(R - \beta(R)) \\ &= NAV_1(\lambda) + \frac{y}{1-\lambda}(R - \beta(R)), \end{aligned}$$

implying that $NAV_2(\lambda) > NAV_1(\lambda)$ for any R because $R > \beta(R)$, and thus any late agent strictly prefer to stay until $t = 2$.

Case 2. Consider the case of $x < \lambda(x + y\beta(R))$, which implies that $l > 0$. Note that equations (2.2) and (2.3) give two conditions to calculate NAV_1:

$$NAV_1(\lambda) = x + (y - \phi l)\beta(R) \tag{A.2}$$
$$= \frac{x + (1-\phi)l\beta(R)}{\lambda}. \tag{A.3}$$

Solving (A.3) as an equation of λ yields:

$$\lambda = \frac{x + (1-\phi)l\beta(R)}{x + (y - \phi l)\beta(R)}. \tag{A.4}$$

At the same time, note that NAV_2 in this case is given by

$$NAV_2(\lambda) = \frac{(y - l)R}{1 - \lambda}. \tag{A.5}$$

Plugging (A.4) into the expression of NAV_2 (A.5) and simplifying yields:

$$NAV_2(\lambda) = x + (y - \phi l)R,$$

which combined with (A.2) immediately leads to

$$NAV_2(\lambda) - x = \frac{R}{\beta(R)}(NAV_1(\lambda) - x).$$

This implies, again, $NAV_2(\lambda) > NAV_1(\lambda)$ for any R because $R > \beta(R)$, and thus any agent strictly prefers to stay until $t = 2$. Taken together, the analysis implies that $\lambda^* = \pi$ is always the unique equilibrium. ∎

Proof of Proposition 1. We first prove part i) for fund equity without swing pricing.

Case 1.1. Consider the case of $x + (1-\phi)y\beta(R) \geq \lambda(x + y\beta(R))$, which implies that the liquidation value $c(x, y) = x + (1-\phi)y\beta(R)$ of the fund is high enough to meet redemption requests at the NAV at $t = 1$ given fundamentals R. Thus, the contract payment at $t = 1$ is given by $c_f(R) = x + y\beta(R)$. Applying Definition 2 yields the first line of (2.7).

Case 1.2. Consider the case of $x + y(1-\phi)\beta(R) < \lambda(x + y\beta(R))$, which implies that the liquidation value of the fund is not high enough to meet redemption requests at the NAV given fundamentals R. The fund fully liquidates, and the liquidation value is distributed on a pro-rata basis to all agents at $t = 1$. Thus, the contract payment at $t = 1$ is given by $c(x, y) = x + (1-\phi)y\beta(R)$. Applying Definition 2 yields the second line of (2.7).

We then prove part ii) for fund equity with swing pricing.

Case 2.1. Consider the case of $x \geq \lambda(x + y\beta(R))$, which implies that stored cash at the fund is enough to meet redemption requests at the NAV at $t = 1$ given fundamentals R. Thus, the fund does not liquidate the illiquid asset, and the contract payment at $t = 1$ is given by $c_s(R, \lambda) = x + y\beta(R)$. Applying Definition 2 yields the first line of (2.8).

Case 2.2. Consider the case of $x < \lambda(x+y\beta(R))$, which implies that stored cash at the fund is not enough to meet redemption requests at the NAV at $t = 1$ given fundamentals R. The fund has to liquidate $l(\lambda)$ illiquid assets to be able to meet redemptions at the after-swing-pricing fund NAV, $c_s(R, \lambda)$, where $l(\lambda)$ and $c_s(R, \lambda)$ are the solutions to equations (2.2) and (2.3). Solving (2.2) and (2.3) yields the contract payment at $t = 1$:

$$c_s(R, \lambda) = \frac{x + (1-\phi)y\beta(R)}{1 - (1-\lambda)\phi}.$$

Applying Definition 2 yields the second line of (2.8).

We finally prove part iii) for bank debt.

Case 3.1. Consider the case of $x + (1-\phi)y\beta(R) \geq \lambda c_b$, which implies that the liquidation value of the bank is high enough to meet withdrawal requests at the deposit value c_b. Thus, the contract payment at $t = 1$ is given by c_b. Applying Definition 2 yields the first line of (2.9).

Case 3.2. Consider the case of $x + y(1-\phi)\beta(R) < \lambda c_b$, which implies that the liquidation value of the bank is not high enough to meet withdrawal requests at the deposit value c_b. The bank defaults, and the liquidation value is distributed on a pro-rata basis to all agents at $t = 1$. Thus, the contract payment at $t = 1$ is given by $c(x, y) = x + (1-\phi)y\beta(R)$. Applying Definition 2 yields the second line of (2.9). ∎

Proof of Proposition 2. We establish the result for the case of $\pi = 0$ and $\phi = 1$ for clarity, and the general result then follows by continuity. Consider a fund without adopting swing pricing. By Lemma 1, the fund is subject to panic runs given any fundamentals R. With run probability q, the fund's problem at $t = 0$ is given by

$$\sup_{x,y\in[0,1]} \int_{[1,+\infty)} \left(qu(x) + (1-q)u(x+yR)\right) dG(R)\,, \text{ s.t. } x + y = 1\,, \tag{A.6}$$

where x is the contract payment, that is, the liquidation value, in the run equilibrium for all agents, while $x + yR$ is the payment for an agent in the no-run equilibrium. Taking first order condition of (A.6) with respect to y yields

$$\begin{aligned} 0 \;=\; & \int_{[1,+\infty)} \left(\left(-qu'(1-y) + (1-q)u'(1-y+yR)(R-1)\right) g(R) \right. \\ & \left. + \left(qu(1-y) + (1-q)u(1-y+yR)\right) g'(R)\right) dR\,, \end{aligned} \tag{A.7}$$

where $g(\cdot)$ is the density function. When $y = 1$, $\lim_{y\to 1} u'(1-y) = \infty$, while all the other terms in the right hand side of (A.7) are finite. Consequently, the right hand side of (A.7) approaches negative infinity when $q > 0$. This implies that the optional allocation on the illiquid asset by this fund must satisfy $y_f^* < 1$.

Now consider the fund adopting swing pricing under the same economic environment. By Lemma 1, the fund is not subject to panic runs; instead, $\lambda^* = \pi = 0$ is the unique equilibrium at $t = 1$ regardless of R. Hence, the fund's problem at $t = 0$ is given by

$$\sup_{x,y\in[0,1]} \int_{[1,+\infty)} u(x + yR)dG(R)\,, \text{ s.t. } x + y = 1\,,$$

the solution to which is $y_s^* = 1$. Therefore, it must be that $y_s^* > y_f^*$, establishing the first result.

We now consider expected LPI given the equilibrium asset allocations y_s^* and y_f^*, using (2.6) in Definition 2. We have:

$$\begin{aligned}
\mathbb{E}[LPI_s^*] &= \frac{1}{1-\phi} - 1 && \text{(A.8)}\\
&> \mathbb{E}\left[\frac{x_f^* + y_f^*\beta(R)}{x_f^* + (1-\phi)y_f^*\beta(R)} - 1\right] && \text{(A.9)}\\
&> (1-q)\mathbb{E}\left[\frac{x_f^* + y_f^*\beta(R)}{x_f^* + (1-\phi)y_f^*\beta(R)} - 1\right] && \text{(A.10)}\\
&= \mathbb{E}[LPI_f^*]\,, && \text{(A.11)}
\end{aligned}$$

where (A.8) follows from Lemma 1 that $\lambda_s^* = 0$ for this fund using swing pricing, and then from the first line of (2.8) in Proposition 1; (A.9) follows from that $y_f^* < 1$ and $x_f^* + y_f^* = 1$; (A.10) follows from that $0 < q < 1$, and (A.11) follows from (2.7) in Proposition 1. ∎

Proof of Proposition 3. We first derive the LPI formula in (2.12).

Case 1. Consider the case of $x \geq \lambda(x+y\beta(R))$, which implies that stored cash at the fund is enough to meet redemption requests at the NAV at $t = 1$ given fundamentals R. Thus, the fund does not liquidate the illiquid asset, and the contract payment at $t = 1$ is given by $x + y\beta(R)$. Applying Definition 2 yields the first line of (2.12).

Case 2. Consider the case of $x < \lambda(x+y\beta(R))$ and $x+(1-\phi)y\beta(R) \geq \lambda(x+y(1-\mu\phi)\beta(R))$, which implies that stored cash at the fund is not enough to meet redemption requests at the NAV at $t = 1$ given fundamentals R, but the full liquidation value of the fund is high enough to meet redemption requests at the partially struck NAV after full liquidation. The fund has to liquidate l illiquid asset to be able to meet redemptions at the partially struck fund NAV (2.11), where l and NAV_1 are the solutions to equations (2.11) and (A.12) below:

$$\lambda NAV_1 = x + (1-\phi)l\beta(R)\,. \tag{A.12}$$

Solving (2.11) and (A.12) yields the NAV at $t = 1$:

$$NAV_1 = \frac{x + (1-\phi)y\beta(R)}{1-(1-\mu\lambda)\phi}\,.$$

Applying Definition 2 yields the second line of (2.12).

Case 3. Consider the case of $x + y(1-\phi)\beta(R) < \lambda(x + y(1-\mu\phi)\beta(R))$, which implies that the liquidation value of the fund is not high enough to meet redemption requests at the partially struck NAV after full liquidation. The fund fully liquidates, and the liquidation value is distributed on a pro-rata basis to all agents at $t = 1$. Thus, the fund NAV at $t = 1$ is given by $x + (1-\phi)y\beta(R)$. Applying Definition 2 yields the third line of (2.12).

We then show that panic runs happen for fund equity with partial NAV striking. Again, it suffices to provide sufficient conditions under which the two equilibria of $\lambda^* = \pi$ and $\lambda^* = 1$ co-exist. Consider $\pi = 0$. For any $0 < \mu < 1$, the payoff gain for a late agent to redeem at $t = 1$ when other late agents all redeem is

$$\Delta(1,1) = x + (1-\phi)y\beta(R) - 0 > 0\,,$$ [23]

while the payoff gain for a late agent to stay until $t = 2$ when other late agents all stay is

$$\Delta(0,0) = x + yR - (x + y\beta(R)) > 0\,,$$

implying that the two equilibria of $\lambda^* = 0$ and $\lambda^* = 1$ co-exist for any R, that is, panic runs happen. ∎

[23] Note that when $\mu = 1$, that is, when full swing pricing is adopted, $\Delta(1,1)$ cannot be calculated this way. Instead, the proof of part ii) of Lemma 1 applies for the case of $\mu = 1$, which shows that a fund adopting full swing pricing is not subject to panic runs.

B General LPI Derivation under Multiple Assets

B.1 Fund Equity without Swing Pricing

Consider two exhaustive cases below. First, when $\sum_{j=0}^{N}(1-\phi_j)y_j\beta_j(R) \geq \lambda\sum_{j=0}^{N} y_j\beta_j(R)$, the liquidation value of the fund is high enough to meet redemption requests at the NAV at $t=1$ given fundamentals R. Thus, the contract payment at $t=1$ is given by $\sum_{j=0}^{N} y_j\beta_j(R)$. Using the definition of portfolio weight (3.1) and applying Definition 2 yield the first line of (3.2).

Second, consider the case of $\sum_{j=0}^{N}(1-\phi_j)y_j\beta_j(R) < \lambda\sum_{j=0}^{N} y_j\beta_j(R)$, in which the liquidation value of the fund is not high enough to meet redemption requests at the NAV given fundamentals R. The fund fully liquidates, and the liquidation value is distributed on a pro-rata basis to all agents at $t=1$. Thus, the contract payment at $t=1$ is given by $\sum_{j=0}^{N}(1-\phi_j)y_j\beta_j(R)$. Using the definition of portfolio weight (3.1) and applying Definition 2 yield the second line of (3.2).

B.2 Fund Equity with Swing Pricing

Under swing pricing, the fund optimally liquidates asset $j+1$ only after it exhausts asset j at $t=1$. The fund also continuously adjusts its NAV to incorporate liquidation costs induced by redemptions. Thus, the fund just exhausts asset J when outflows λ_J satisfy:

$$\sum_{j=0}^{J}(1-\phi_j)y_j\beta_j(R) = \lambda_J\left(\sum_{j=0}^{J}(1-\phi_j)y_j\beta_j(R) + \sum_{j=J+1}^{N} y_j\beta_j(R)\right), \tag{B.1}$$

where the left-hand side of (B.1) is the cash raised by liquidating up to just exhausting asset J, while the sum of the two terms in the parentheses in the right-hand side of (B.1) is the adjusted fund NAV after using swing pricing.

Consequently, when fund outflows satisfy $\lambda_{J-1} < \lambda \leq \lambda_J$, where λ_J is given by (B.1), the fund has already exhausted asset $J-1$ and is liquidating asset J to meet redemptions. Denote by l_J the amount of asset J that the fund has to liquidate. The adjusted NAV at $t=1$ after using swing pricing is given by

$$NAV_1 = \sum_{j=0}^{J-1}(1-\phi_j)y_j\beta_j(R) + (y_J - \phi_J l_J)\beta_J(R) + \sum_{j=J+1}^{N} y_j\beta_j(R)\,, \tag{B.2}$$

while the total cash being raised to meet flows are given by

$$\lambda NAV_1 = \sum_{j=0}^{J-1}(1-\phi_j)y_j\beta_j(R) + (1-\phi_J)l_J\beta_J(R)\,. \tag{B.3}$$

Solving the system of equations (B.2) and (B.3) gives NAV_1 as a function of λ, and then using the definition of portfolio weight (3.1) and applying Definition 2 yields (3.4).

B.3 Bank Debt

Define

$$w'_j = \frac{\mathbb{E}[y_j\beta_j(R)]}{\sum_{j=0}^{N} y_j\beta_j(R)}\,. \tag{B.4}$$

Consider two exhaustive cases below. First, when $\sum_{j=0}^{N}(1-\phi_j)y_j\beta_j(R) \geq \lambda\sum_{j=0}^{N}\mathbb{E}[y_j\beta_j(R)]$, the liquidation value of the bank is high enough to meet withdrawals at the deposit value. Thus, the contract payment at $t=1$ is given by $\sum_{j=0}^{N}\mathbb{E}[y_j\beta_j(R)]$. Using the definition of portfolio weight (B.4) and applying Definition 2 yield the first line of (3.5).

Second, consider the case of $\sum_{j=0}^{N}(1-\phi_j)y_j\beta_j(R) < \lambda\sum_{j=0}^{N}\mathbb{E}[y_j\beta_j(R)]$, in which the liquidation value of the bank is not high enough to meet withdrawals at the deposit value. The bank defaults, and the liquidation value is distributed on a pro-rata basis to all agents at $t=1$. Thus, the contract payment at $t=1$ is given by $\sum_{j=0}^{N}(1-\phi_j)y_j\beta_j(R)$. Using the definition of portfolio weight (B.4) and applying Definition 2 yield the second line of (3.5).

B.4 Fund Equity with Partial NAV Striking

As discussed in Section 2.4, mutual funds may engage in partial NAV striking in reality without formally implementing swing pricing. Accordingly, we can empirically construct an LPI for fund equity adjusting for the practice of partial NAV striking, serving as a robustness check for the LPI for fund equity without swing pricing.

Generalizing (2.12) in Proposition 3, we derive the LPI of fund equity with partial NAV striking as:

$$LPI_{f;\mu} = \begin{cases} \dfrac{1}{1-\overline{\phi}} - 1 & \lambda \leq \lambda_0 \\ \dfrac{1}{1-\overline{\phi}} \dfrac{\sum_{j=0}^{J-1}(1-\mu\phi_j-(1-\mu)\phi_J)w_j + \sum_{j=J}^{N}(1-\phi_J)w_j}{1-(1-\mu\lambda)\phi_J} - 1 & \lambda_{J-1} < \lambda \leq \lambda_J \\ 0 & \lambda > \lambda_N \end{cases} \tag{B.5}$$

where $\lambda_0 = w_0$ as defined in (3.1), $\overline{\phi}$ is given by (3.3), and

$$\lambda_J = \frac{\sum_{j=1}^{J} w_j(1-\phi_j)}{\sum_{j=1}^{J} w_j(1-\mu\phi_j) + \sum_{j=J+1}^{N} w_j}\,, \text{ for } 1 \leq J \leq N\,.$$

Also recall that μ captures the intensity of NAV-striking: the higher μ is, the more liquidation costs the mutual fund incorporates into its end-of-day NAV without the formal implementation of swing pricing.

Importantly, we do not adjust the asset allocations w or outflows λ in (B.5) as we did for the LPI for fund equity with swing pricing (3.4) in Section 3.2.2. This is consistent with the purpose of this robustness check that we take the observed asset allocations and outflows in the data as outcomes of mutual funds engaging in partial NAV striking in reality. Given that we do not know how intensively mutual funds strike the NAV in reality, we provide a sensitivity analysis by exhausting all possible values of μ with an increment of 10%, without estimating the actual μ that mutual funds use, which is difficult to measure empirically.

To derive (B.5), consider three exhaustive cases. First, when $y_0 \geq \lambda \sum_{j=0}^{N} y_j \beta_j(R)$, stored cash at the fund is enough to meet redemption requests at the NAV at $t = 1$ given fundamentals R. Thus, the fund does not liquidate any of the illiquid assets and the contract payment at $t = 1$ is given by $\sum_{j=0}^{N} y_j \beta_j(R)$. Applying Definition 2 yields the first line of (B.5).

Second, when $y_0 < \lambda \sum_{j=0}^{N} y_j \beta_j(R)$ and $\sum_{j=0}^{N}(1-\phi_j) y_j \beta_j(R) \geq \lambda \sum_{j=0}^{N}(1-\mu\phi_j) y_j \beta_j(R)$, stored cash at the fund is not enough to meet redemption requests at the NAV at $t = 1$ given fundamentals R, but the full liquidation value of the fund is high enough to meet redemption requests at the partially struck NAV. In this case, the fund strikes its NAV to partially incorporate liquidation costs induced by redemptions. The fund just exhausts asset J when outflows λ_J satisfy:

$$\sum_{j=0}^{J}(1-\phi_j) y_j \beta_j(R) = \lambda_J \left(\sum_{j=0}^{J}(1-\mu\phi_j) y_j \beta_j(R) + \sum_{j=J+1}^{N} y_j \beta_j(R) \right), \tag{B.6}$$

where the left-hand side of (B.6) is the cash raised by liquidating up to just exhausting asset J, while the sum of the two terms in the parentheses in the right-hand side of (B.6) is the fund NAV after using partial NAV striking. Consequently, when fund outflows satisfy $\lambda_{J-1} < \lambda \leq \lambda_J$, where λ_J is given by (B.6), the fund has already exhausted asset $J - 1$ and is liquidating asset J to meet redemptions. Suppose the fund has to liquidate l_J of asset J. The NAV at $t = 1$ after using partial NAV striking is given by

$$NAV_1 = \sum_{j=0}^{J-1}(1-\mu\phi_j) y_j \beta_j(R) + (y_J - \mu\phi_J l_J)\beta_J(R) + \sum_{j=J+1}^{N} y_j \beta_j(R)\,, \tag{B.7}$$

while the total cash being raised to meet flows is given by

$$\lambda NAV_1 = \sum_{j=0}^{J-1}(1-\phi_j) y_j \beta_j(R) + (1-\phi_J) l_J \beta_J(R)\,. \tag{B.8}$$

Solving the system of equations (B.7) and (B.8) gives NAV_1 as a function of λ, and then using the definition of portfolio weight (3.1) and applying Definition 2 yields the second line of (B.5).

Finally, consider the case of $\sum_{j=0}^{N}(1-\phi_j) y_j \beta_j(R) < \lambda \sum_{j=0}^{N}(1-\mu\phi_j) y_j \beta_j(R)$, which implies that the liquidation value of the fund is not high enough to meet redemption requests at the partially struck NAV after full liquidation. The fund fully liquidates, and the liquidation value is distributed on a pro-rata basis to all agents at $t = 1$. Thus, the fund NAV at $t = 1$ is given by $\sum_{j=0}^{N}(1-\phi_j) y_j \beta_j(R)$. Using the definition of portfolio weight (3.1) and applying Definition 2 yields the third line of (B.5).

Internet Appendix for

Bank Debt versus Mutual Fund Equity in Liquidity Provision

Yiming Ma Kairong Xiao Yao Zeng

A Deposit Insurance in LPI

Although our framework does not focus on deposit insurance, this appendix clarifies two points regarding the role of deposit insurance in the construction of bank LPI. First, we show that bank LPI captures the liquidity provision capacity of uninsured deposits rather than insured deposits. Second, we illustrate that the LPI construction for uninsured bank deposits is still valid if the bank is partially funded by insured deposits.

We first note that our bank LPI construction already excluded the direct effect of deposit insurance because the contract payment of bank debt drops to the liquidation value of the underlying bank asset portfolio after the bank defaults. The contract payment of insured deposits would remain at the promised deposit value because the promised deposit value is honored regardless of bank default. Hence, our LPI captures liquidity provision by uninsured rather than insured deposits.

We further show that the LPI construction for uninsured bank deposits remains valid in the presence of deposit insurance. According to the theoretical models that focus on deposit insurance (e.g., Allen, Carletti, Goldstein and Leonello, 2018, Davila and Goldstein, 2022), a higher proportion of insured deposits leads to: 1) a lower run probability, and consequently, 2) a less liquid bank portfolio. Intuitively, having more insured deposits renders the bank safer as a whole and encourages it to hold a less liquid portfolio. The LPI construction captures these two equilibrium outcomes by incorporating 1) empirically observed outflows and 2) the actual bank asset portfolio. Thus, any spillover effects of deposit insurance on the liquidity provision by uninsured deposits will be picked up by the LPI and will not invalidate the bank LPI construction.

To illustrate the logic above, consider a hypothetical bank that is fully financed by uninsured deposits. Suppose the deposit value is $1, the bank has 20% cash and 80% illiquid loans given economic fundamentals, where the loans, if liquidated at short notice, can be only recovered at 60% of their fair value (i.e., the haircut is 40%). In this setting, the liquidation value of the asset portfolio is $1 \times \$0.2 + (1 - 40\%) \times \$0.8 = \$0.68$. The LPI of bank debt given any outflows can be directly calculated following (2.9) in Proposition 1. For example, if total outflows amount to 1%, withdrawing depositors will get the full deposit value \$1, and the realized LPI is $1/0.68 - 1 = 0.47$, while if total outflows amount to 99%, the bank defaults, and the realized LPI is $0.68/0.68 - 1 = 0$. Concerning expected LPI, let the distribution of endogenous outflows be a triangular distribution with a density function of $f(\lambda) = 2\lambda$. Thus, a dollar invested in uninsured deposits generates an expected LPI of $\left(\int_0^{0.68} 2\lambda d\lambda + 0.68 \int_{0.68}^{1} 2\lambda d\lambda\right)/0.68 - 1 = 0.22$.

Now suppose that the bank is funded by 50% insured deposits and 50% uninsured deposits instead. Consistent with the theoretical argument above, this bank would have less volatile outflows, and consequently, a less liquid asset portfolio. For example, suppose that the empirical distribution of outflows becomes uniform on [0,1] and that the asset portfolio becomes 10% cash and 90% loans given fundamentals. In this setting, the liquidation value of the asset portfolio is $1 \times \$0.1 + (1 - 40\%) \times \$0.9 = \$0.64$. In this case, the LPI of bank debt, that is, uninsured deposits of this bank, can be still directly calculated following (2.9) in Proposition 1. For example, if total outflows amount to 1%, withdrawing depositors will get the full deposit value \$1, and the realized LPI is $1/0.64 - 1 = 0.56$, while if total outflows amount to 99%, the bank defaults, and the realized LPI is $0.64/0.64 - 1 = 0$. Concerning expected LPI, a dollar invested in uninsured deposits generates an expected LPI of $\left(\int_0^{0.64} d\lambda + 0.64 \int_{0.64}^{1} d\lambda\right)/0.64 - 1 = 0.36$. Compared to the earlier case without insured deposits, the LPI of uninsured deposits increased by $(0.36 - 0.22)/0.22 = 64\%$, which suggests that deposit insurance indirectly contributes to the LPI of uninsured deposits. In other words, in addition to illustrating the validity of the LPI construction in the presence of deposit insurance, the example above also suggests that deposit insurance indirectly improves the liquidity provision capacity of a bank's uninsured deposits. To further isolate the effect of debt versus equity in liquidity provision from the effect of deposit insurance, we perform several additional tests in Section 4.

B Outflow-Adjusted Haircuts

In our baseline estimates, haircuts for different asset classes are taken as the median market haircuts in each quarter. Nevertheless, the liquidation costs may vary with outflows.

We do not observe the actual liquidation costs for each fund and bank but we have some information about the distribution of haircuts for each asset class in each quarter. Therefore, we resort to assigning haircuts from the distribution to each fund depending on the size of their outflows and hence liquidations. Funds with larger redemptions induce larger price pressures and are mapped to have a larger haircut from the distribution.

In the data, we observe the 10th, 50th, and 90th percentile of haircuts for each security type j in each quarter t, i.e., $\phi_{j,t}(10)$, $\phi_{j,t}(50)$, and $\phi_{j,t}(90)$. Please refer to Table A2 in this Internet Appendix for summary statistics. We also observe the cross-sectional distribution of outflows $\lambda_{i,t}$ in each quarter. Assuming that the correspondence between the percentile of haircuts and the percentile of outflows is piece-wise linear, we can establish a correspondence between these two distributions by linear interpolation. Specifically, if fund i has an outflow ranked at the pth percentile in the distribution of outflows at time t, we estimate the effective haircut it incurs to be $\hat{\phi}_{i,j,t}(p)$:

$$\begin{cases} \hat{\phi}_{i,j,t}(p) = \phi_{j,t}(10) & \text{if} \quad p < 10\,, \\ \hat{\phi}_{i,j,t}(p) = \phi_{j,t}(10) + (p-10)\frac{\phi_{j,t}(50)-h_{j,t}(10)}{40} & \text{if} \quad 10 \leq p < 50, \\ \hat{\phi}_{i,j,t}(p) = \phi_{j,t}(50) + (p-50)\frac{\phi_{j,t}(90)-\phi_{j,t}(50)}{40} & \text{if} \quad 50 \leq p \leq 90, \\ \hat{\phi}_{i,j,t}(p) = \phi_{j,t}(90) & \text{if} \quad p > 90 \end{cases}$$

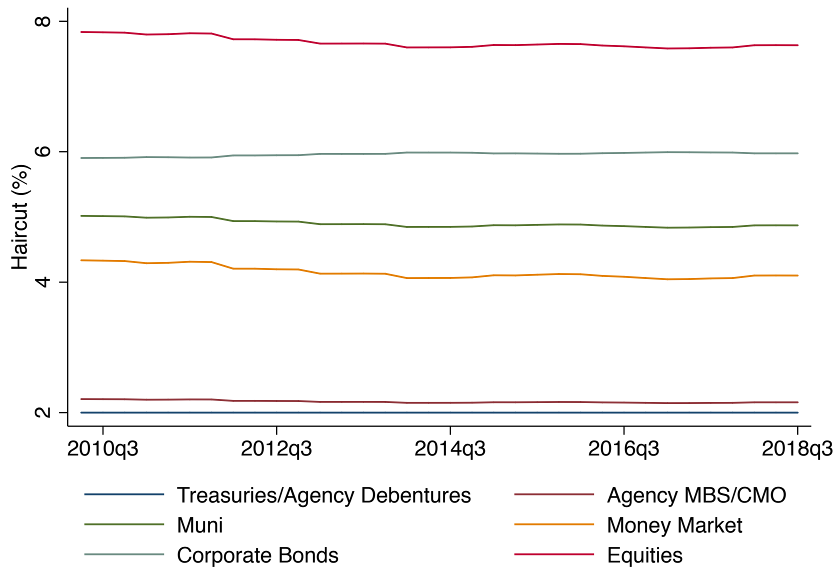
For instance, if a fund experiences a medium outflow, then the haircuts that it incurs when liquidating an asset is the medium haircut. We do not observe haircut distributions for loans and continue to apply the median haircuts as in the baseline estimate.[2]

[2]Real estate loan and consumer loan haircuts are determined by regulators and are not subject to price pressure as in private markets. Commercial loans are traded in secondary markets and are subject to price pressure. Unfortunately, we were unable to obtain the relevant data series from the LSTA. This data gap mainly affects banks, for whom we will show the LPI estimates to be relatively insensitive to haircut adjustments.

Table 4 shows the distribution of fund and bank LPIs using outflow-adjusted haircuts. The LPI for funds with haircut adjustments is slightly above the baseline estimate per dollar. The distribution of bank LPIs remains largely unchanged.

Figure A1: Haircuts

This graph plots the haircuts for different asset categories over time. Securities haircut data (upper panel) is obtained from the Federal Reserve Bank of New York's published repo series. Haircuts for commercial loans, real estate loans, and personal loans (lower panel) are from the Loan Syndications and Trading Association (LSTA), the Federal Home Loan Banks website, and the Federal Reserve, respectively. To remove outliers in the original data, we calculate the first principal component of the underlying series and plot the predicted value from the loadings regression $\phi_{k,t} = a_k + b_k PC_t + \epsilon_{k,t}$ for each asset category k.



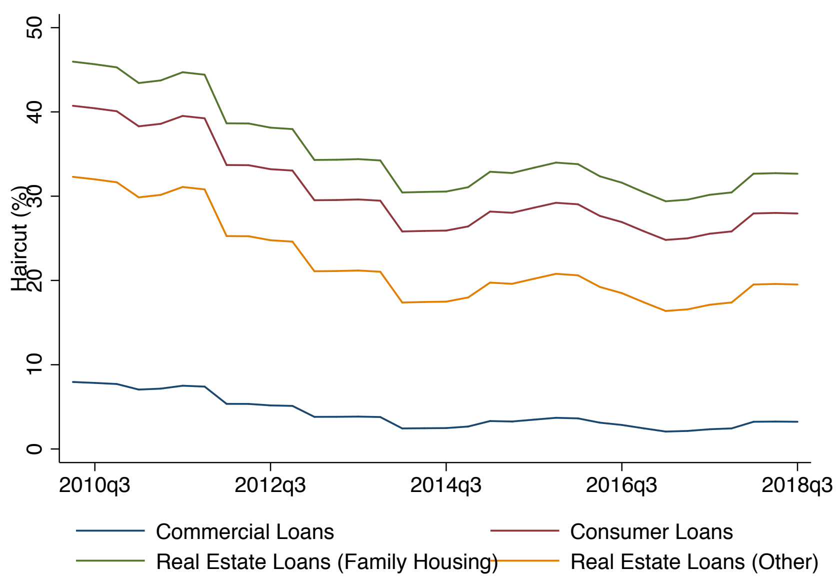


Table A1: Asset Category Sources

This table shows the sources for banks and funds for each asset class used in the LPI calculation. Bank asset holdings are obtained using bank balance sheet data from call reports. The bank holdings variables all come from RCFD (for example, the corresponding cash variable is RCFD0010) except for real estate loans which also take variables from RCON. Mutual fund holdings data is obtained from the CRSP database, and fund cash holdings are taken from CRSP mutual funds summary data. For fund holdings, all asset classes except cash holdings are categorized directly from securities-level holdings using the mapping shown.

Category	Bank Source (RCFD)	Fund Holdings Mapping
1. Treasuries &	3531, 0213, 1287	US Government & Agency Bills, Bonds,
Agency Debentures	3532, 1290, 1293, 1295, 1298	Notes, Strips, Trust Certificates
2. Agency MBS & CMO	G301, G303, G305, G307, G313, G315, G317, G319	Agency MBS, TBA MBS, CMO,
	K143, K145, K151, K153, G379, G380, K197	Pass Through CTF, REMIC, ARM
3. Commercial Loans	F610, F614, F615, F616, K199, K210, F618	Syndicated Loans, Term Deposits,
	$(2122 - 3123) - 1975 - 1410$ if ≥ 0	Term Loans
4. Money Market		Money Market, CDs, Corporate Paper
5. Municipal	8499, 8497, 3533	Municipality Debt
6. Corporate Bonds	G386, 1738, 1741, 1743, 1746	Bonds, MTN, Foreign Gov'ts & Agencies
7. Equities	A511	Equities, Funds, Convertible bonds
8. Private ABS & CMO	G309, G311, G321, G323, K147, K149, K155, K157	ABS, CMO, CDO, CLO, Covered Bonds
9. Consumer Loans	1975	
10. Real Estate Loans (Family)	$1410 * (RCON3465/RCON3385)$	
11. Real Estate Loans (Other)	$1410 * (RCON3466/RCON3385)$	
12. Cash	0010	CRSP Mutual Funds summary Cash %
13. Fixed Assets	3541, 3543, total assets - sum of above variables	

Table A2: Distribution of Haircuts

This table shows the 10^{th}, 50^{th}, and 90^{th} percentile of haircuts for security categories obtained from the Federal Reserve Bank of New York's repo series from 2011 to 2017.

	(1) p10 Haircut	(2) p50 Haircut	(3) p90 Haircut
Treasuries	0.9	2.0	2.7
Agency Debentures	1.9	2.0	3.6
Agency MBS/CMOs	2.0	2.2	3.9
CMO/ABS	3.0	7.5	16.4
Money Market	1.9	4.2	5.0
Municipal Bonds	2.0	4.9	10.1
Corporate Bond	3.0	6.0	10.9
Equity	5.0	7.7	15.0