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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 develop a unified theoretical framework and empirically show that mutual funds issuing demandable equity also provide an economically significant amount of liquidity by insuring against idiosyncratic liquidity shocks. Quantitatively, bond funds provide 12.5% of the liquidity that banks provide per dollar. Our model further shows that when equity values incorporate the liquidation cost from redemptions, as in swing pricing, liquidity provision is not necessarily reduced. This is because swing pricing may increase funds' capacity for holding illiquid assets without inducing panic 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 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 how much liquidity equity-issuing intermediaries can provide. After all, mutual funds also invest in illiquid assets like corporate bonds and issue shares redeemable at short notice.

This paper develops a unified theoretical framework for liquidity provision by debt- and equity-issuing intermediaries. We theoretically show that demandable equity shares can also allow investors' idiosyncratic liquidity risks to be shared so that debt is not a prerequisite for liquidity provision. We then 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 portfolio choices and flows. The LPI measures how much an intermediary's contract payment value exceeds the direct liquidation value of the underlying assets without the intermediary, which is effectively the intermediary's contribution to liquidity provision.

We apply the LPI to quantify liquidity provision by banks and funds. Our estimates show that bond mutual fund shares provide 12.5% of the liquidity that bank deposits provide per dollar. That is, relative to bank debt, fund equity provides an economically significant but smaller amount of liquidity. This result is echoed by our LPI estimates for money market funds (MMFs). When prime institutional MMFs switched from a debt-like fixed \$1 net asset value (NAV) to an equity-like floating NAV following the 2016 Money Market Reform, their liquidity provision decreased but remained significant.

At the same time, the appropriate design and regulation of equity-funded intermediaries have been brought into the limelight by the Covid-19 crisis. The U.S. SEC has recently proposed to mandate swing pricing for open-end mutual funds.[1] Swing pricing adjusts a fund's net asset value (NAV) to pass costs stemming from shareholder redemption activities on to the redeeming shareholders. One concern is that this downward adjustment of fund equity values with large outflows could hurt investors in need of liquidity. Using our theoretical framework, we show that swing pricing may not necessarily constrain liquidity provision because it also reduces the need for holding large amounts of liquid assets in meeting redemption requests. Funds may actually hold more illiquid assets and transform more liquidity in equilibrium.

We begin by formulating liquidity provision under a unified framework, 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 are realized, they make investment decisions between liquid cash and an illiquid long-term asset with pre-mature liquidation costs. This allocation can be done through intermediaries such as banks that issue demandable debt or mutual funds that issue demandable equity. The promised value of bank dept is fixed while fund equity values vary with the underlying asset prices but not with the amount of investor outflows.

In the model, we define an intermediary's liquidity provision as how much its contract payments exceed the direct liquidation value of the underlying assets. In this sense, liquidity is provided when investors' idiosyncratic liquidity shocks are pooled at the intermediary level, regardless of whether the contract issued is debt or equity. However, contract design affects the extent of liquidity provision. We conduct comparative statics to explore how liquidity provision varies with asset illiquidity and contract type. When the underlying asset is relatively liquid, liquidity provision capacity is small. Bank debt fares relatively better in providing liquidity because it offers the most stable contract payments while the potential for run-induced liquidation costs is minimal. As asset illiquidity increases, the wedge between bank debt and fund equity in liquidity provision widens because the fund increases cash holdings by more due to its less stable contract payments.

Based on the model, we then derive the LPI as the first measure of liquidity provision that is applicable to financial institutions regardless of the contractual form of their liabilities. The LPI requires three inputs: asset holdings, asset liquidation costs, and outflows. In each quarter, we calculate the contract payment given outflows for each institution. For banks, depositors obtain

[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.

the face value of debt unless the bank defaults and the proceeds are distributed proportionately. For fund equity, 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. Finally, we calculate the 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 a sizable amount of liquidity compared to commercial banks. Over our sample period from 2011 to 2017, the average fund provides 21.7 bps of liquidity per dollar. In comparison, the average bank provides 173.4 bps of liquidity per dollar. In other words, a dollar invested in the average fixed-income mutual fund transforms around 12.5% 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.

We further consider how robust our LPI estimates are against several institutional features. For funds, we first recompute the LPI considering a time-varying order of liquidations and find that fund LPI is lower when a proportional liquidation order is applied in periods of high volatility. Second, we adjust fund LPI allowing for partial NAV striking and find that results remain largely unchanged. Third, for banks, 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 decreases in this case, which further shrinks the gap between fund and bank liquidity provision.

We then apply our LPI to 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 provided a natural control group. Our estimates confirm that 91.5% to 93.8% of liquidity provision is preserved after the reform, corroborating the evidence from bond mutual funds that liquidity provision by demandable equity is economically significant but less than that by demandable debt. The gap in liquidity provision is smaller in the MMF context because MMFs are constrained to only choose short-term assets that are relatively liquid.

Finally, we use our unified framework to analyze fund equity with swing pricing. Based on our model, we derive a swing pricing adjustment that varies the equity value received by redeeming investors not only with asset prices but also with fund outflows to incorporate liquidation costs. We derive the LPI for fund equity with swing pricing and find that it may actually exceed the LPI of fund equity without swing pricing. This improvement arises because swing pricing reduces the need to hold liquid reserves to meet panic-driven outflows. Consequently, the fund can hold more illiquid assets and provide more liquidity. We end with a discussion of estimating liquidity provision by fund equity with swing pricing in practice and a comparison with liquidity provision by exchange-traded funds (ETFs).

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. 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.[2] Similarly, pronounced outflows also materialized in U.S. bond mutual funds, which led 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 may be further improved.

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

[2]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/`.

provision.[3] We provide a unified framework to measure and compare liquidity provision by banks and funds. We empirically show that demandable-equity-funded intermediaries 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 non-banks. Among them, mutual funds provide liquidity but are subject to panic runs, 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) find widespread stale pricing in bond mutual funds, while Giannetti and Jotikasthira (2023) find that mutual funds with larger shares of a bond sell that bond to a lower extent when experiencing redemptions. Kacperczyk and Schnabl (2013), Sunderam (2015), Parlatore (2016), Schmidt, Timmermann and Wermers (2016) analyze the financial stability implications of money market mutual funds, while Ma, Zeng and Zhang (2024) study the determinants of run risk at USD stablecoins. Our theory formalizes liquidity provision by demandable 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.

Further, 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).[4] 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 as well as the interdependence between values and flows. The LPI can be estimated using commonly available data and provides a useful tool for monitoring the landscape of liquidity provision going forward.

[3] A partial list of other papers on bank versus shadow bank liquidity includes Gorton and Metrick (2010), Stein (2012), Li, Ma and Zhao (2020) and Xiao (2020).

[4] In Section 3.3, we provide a detailed comparison of our LPI to the existing measures in this literature.

Finally, our paper contributes to the fast-growing literature on swing pricing. Most closely related to our paper is Jin, Kacperczyk, Kahraman and Suntheim (2022), which provides the first empirical evidence that the adoption of swing pricing mitigates outflows during stress events and reduces fund cash holdings using unique data on U.K. corporate bond funds. 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 in equilibrium.

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 results for bank and mutual fund LPI. Section 5 applies the LPI to MMFs and Section 6 analyzes fund equity with swing pricing. Section 7 concludes.

2 Theoretical Framework

We build a theoretical framework to formalize the notion of liquidity provision by financial intermediaries issuing demandable claims. We consider bank deposits, which represent a debt contract, and mutual fund shares, which represent an equity contract. Our model captures the essential characteristics of demandable debt and equity claims and establishes a unified measure of liquidity provision. In Section 6, we further incorporate mutual funds that use swing pricing to adjust their equity value into this framework. The proofs are 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 refer to R as 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.[5]

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 $t = 1$ is $(1 - \phi)\beta(R)$, where $0 < \phi \leq 1$ captures the extent of asset illiquidity. Below, we call ϕ as liquidation cost. Economically, ϕ captures that the liquidation of loans and bonds in secondary markets can depress their prices (see Duffie, 2010, for a review). 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 shocks and the aggregate state of the economy are realized. 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

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

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 fund equity in liquidity provision and to develop a unified measure to compare them. To this end, we compare two scenarios with different contractual arrangements at $t = 0$ given the same underlying economy.[6]

In both 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 $k \in \{b, f\}$ denotes the intermediary and contractual type: a bank (b) issuing debt or a fund (f) issuing equity. 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.

In the first scenario, the representative bank offers a standard demandable debt contract to agents at $t = 0$. The bank chooses the optimal debt payment value at $t = 1$, c_b, which 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). Note that we focus on uninsured deposits. We discuss how our framework also accommodates bank deposits with deposit insurance in Section 2.3, Section 4.2, and Internet Appendix A.

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 investor

[6] 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.

redemptions. In Section 6 below, we further extend the contracting space for fund equity by allowing the contract payment to depend on both fundamentals R and flows λ and show how these two dimensions affect equilibrium outcomes separately.

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, "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."[7] 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." These observations are consistent with the fund equity contract in our model, where the amount of redemptions is not directly contractable. In Internet Appendix B, we consider the case in which the mutual fund can partially strike its NPV so that the value of fund equity partially respond to redemptions. We show that the qualitative predictions remain the same as in our baseline case. In Section 6, we further analzye fund equity with swing pricing, where the NAV fully incorporates the liquidation cost induced by investor redemptions.

With the above two 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.[8] Note that the fund equity contract is 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 contract that we consider is

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

[8]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.

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 two 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*

$$c(x, y) = x + y(1 - \phi)\beta(R)\,. \tag{2.1}$$

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):*

$$LPI_k = \frac{c_k^*(R, \lambda)}{c(x_k, y_k)} - 1\,, \tag{2.2}$$

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,*

$$\mathbb{E}[LPI_k^*] = \int_{[1,+\infty)} \left(\frac{c_k^*(R, \lambda)}{c(x_k^*, y_k^*)} - 1 \right) dG(R)\,, \tag{2.3}$$

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.[9] 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 (2.2) and (2.3), 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 with Given Asset Portfolios

Before characterizing liquidity provision, we first examine how the design of contract payments affects panic runs with given portfolio allocations for fund equity.

Lemma 1. *Given the intermediary portfolio allocation (x, y), fund equity $c_f(R)$ 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.*

Lemma 1 shows that fund equity, despite its NAV flexibly adjusting with fundamentals, cannot eliminate panic runs. 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, consistent with the findings in Chen, Goldstein and Jiang (2010) and Goldstein, Jiang and Ng (2017). Compared to the existing literature, Lemma 1 highlights the separate contractability of economic fundamentals and investor redemptions. It 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.

[9] 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.

We then characterize the magnitude of liquidity provision by fund equity and bank debt for a given portfolio allocation using (2.2) from Definition 2. This characterization provides a micro-foundation for our empirical measure of liquidity provision, which we explain in Section 3. In Section 6, we further demonstrate that this framework can be extended to capture liquidity provision by fund equity with swing pricing.

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

$$LPI_f = \begin{cases} \dfrac{x + y\beta(R)}{x + (1-\phi)y\beta(R)} - 1 & \lambda \leq \dfrac{x + (1-\phi)y\beta(R)}{x + y\beta(R)}, \\ 0 & \lambda > \dfrac{x + (1-\phi)y\beta(R)}{x + y\beta(R)}. \end{cases} \tag{2.4}$$

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

$$LPI_b = \begin{cases} \dfrac{c_b}{x + (1-\phi)y\beta(R)} - 1 & \lambda \leq \dfrac{x + (1-\phi)y\beta(R)}{c_b}, \\ 0 & \lambda > \dfrac{x + (1-\phi)y\beta(R)}{c_b}. \end{cases} \tag{2.5}$$

Proposition 1 offers a unified account to understand the nature and magnitude of liquidity provision by fund equity and bank debt. It shows that demandable equity, just like demandable debt, provides liquidity by allowing investors' idiosyncratic liquidity risks to be shared. In this sense, debt is not a prerequisite for liquidity provision. Specifically, as shown in the first line of (2.4), 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, bank debt provides liquidity in the same way as shown in the LPI expression (2.5). We note that (2.5) applies regardless of how c_b is determined in equilibrium. The comparison between (2.4) and (2.5) also echoes the fact that fund equity is still subject to runs in liquidity provision just as bank debt is. When panic runs occur, agents only receive the liquidation value of the underlying assets, and no liquidity is provided.

2.3 Which Intermediary Provides More Liquidity

We numerically solve for the full equilibrium of optimal portfolio choice at $t = 0$ for different contractual arrangements and investigate how expected LPIs change under optimal asset allocations.[10] This analysis aids in comparing the nature and magnitude of liquidity provision across the three contractual arrangements. It also illuminates the optimal contractual arrangement for liquidity provision under different economic conditions.

Our selection of functional forms and parameter values follows Davila and Goldstein (2022), who calibrate a Diamond-Dybvig-style model on optimal deposit insurance.[11] Specifically, we model investors with isoelastic utility, featuring an elasticity of intertemporal substitution of $1/\gamma$, where $\gamma = 1.5$. We set the proportion of early investors to $\pi = 0.3$. Asset fundamentals R are modeled to follow an exponential distribution with parameter $\eta = 5$, and the function $\beta(R)$ is defined as $\beta(R) = \frac{1}{2}(1 + R)$. Lastly, we set the sunspot probability at $q = 0.3$.

In Figure 2, we show the expected LPI (Panel (a)) and the optimal portfolio share of the illiquid asset y (Panel (b)), for bank debt (black solid lines) and mutual fund equity without swing pricing (red solid lines). This analysis sheds light on how liquidity provision varies across contractual arrangements and the illiquidity of the underlying assets.

When the liquidation cost ϕ is relatively small, the capacity for liquidity provision is limited. The lower LPI arises because the cost of direct liquidation is low, which constrains the capacity for an intermediary to provide liquidity. In comparison, bank debt offers the highest expected LPI (Panel (a)) even without the highest proportion of illiquid assets (Panel (b)). This is because when ϕ is low, the liquidation costs borne by agents during a panic run are low, so that the difference in portfolio holdings has a smaller impact on liquidity provision. Instead, the superior liquidity provision by bank debt arises from the stability of fixed contract payments with respect to changes in economic fundamentals.

As the liquidation cost ϕ increases, LPIs rise but the gap in LPIs between bank debt and mutual fund equity widens (Panel (a)). This is because the fund reduces its holding of the illiquid

[10] In general, obtaining analytical solutions for portfolio choices in Diamond-Dybvig-style models is not feasible even under specific assumptions about utility functions and distributions.

[11] Davila and Goldstein (2022) calibrate their model to target specific moments in the U.S. banking sector. We use their calibrated parameters to qualitatively understand the roles of different financial intermediaries in liquidity provision rather than pursuing a fully quantitative analysis.

asset by more than the bank does due to fund equity's less stable contract payments (Panel (b)). This finding further suggests that for MMFs, which are restricted to investing in relatively liquid assets with maturities under one year, the difference in liquidity provision between debt and equity would be smaller compared to bond funds and banks, which are allowed to invest in more illiquid asset classes.

Finally, we explore the impact of deposit insurance on liquidity provision. We consider a case of full deposit insurance that eliminates panic runs and provide a more detailed illustration in Internet Appendix A. The liquidity provision and illiquid asset holding of banks with full deposit insurance is shown in the black dashed line in Figure 2, Panels (a) and (b), respectively. We observe that when the liquidation cost ϕ is sufficiently high, liquidity provision by bank debt with deposit insurance exceeds liquidity provision by fund equity and bank debt without deposit insurance. This is because deposit insurance eliminates run risk and allows for a larger fraction of illiquid assets to be held. These findings align with the perspective that banks, particularly those with more insured deposits, are ideally suited to holding relatively illiquid assets (e.g., Hanson, Shleifer, Stein and Vishny, 2015, Egan, Hortacsu and Matvos, 2017).

3 Liquidity Provision Index (LPI)

An advantage of our framework is the tight link between the theory and empirical construction of LPI. In this section, 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 provide a step-by-step explanation in Section 3.1 and discuss the data sources in Section 3.2.

3.1 Construction of LPIs

We show how the LPIs derived in Proposition 1 can be empirically constructed using data on intermediaries' portfolio holdings, asset liquidation costs, and outflows. In this process, we generalize the baseline model in Section 2 to accommodate multiple assets. Derivations for the multi-asset extension are provided in Appendix C.

Suppose there are $N \geq 1$ illiquid assets. Assets are ranked by their investor-type-independent unit liquidation cost $0 < \phi_1 \leq \phi_2 \leq ... \leq \phi_N$, 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.

3.1.1 Fund Equity

First, we empirically construct the LPI for fund equity without swing pricing. Generalizing (2.4) in Proposition 1 to the multi-asset case following the derivations in Appendix C.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 liquidation discount of the observed fund portfolio.

The empirical LPI formula (3.2) only requires data on portfolio holdings w_j, asset liquidation discounts 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.

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 Internet Appendix B. 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.[12] We report these results in Section 4.1.

3.1.2 Bank Debt

As a benchmark, we empirically construct the LPI for bank debt. Compared to the LPIs for fund equity, the main challenge for bank debt is that the optimal 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 are realized. With this formulation, we generalize the LPI of bank debt from (2.5) in Proposition 1 to

$$LPI_b = \begin{cases} \dfrac{1}{1-\overline{\phi}'} - 1 & \lambda \leq 1 - \overline{\phi}' \\ 0 & \lambda > 1 - \overline{\phi}', \end{cases} \tag{3.4}$$

where

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

is the value-weighted average liquidation discount 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 C.2. 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 $t-1$.

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

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

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

Our formulation of bank LPI comes with a few assumptions. First, following Diamond and Dybvig (1983), we assume that all 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. 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 in Section 4.2.

3.2 Data

In this section, we summarize our main data sources and variables. We provide further details in Internet Appendix C.

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. We exclude ETFs 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 the liquidation cost ϕ_j of corporate bonds, we use the standard transaction-based liquidity measure in the corporate bond literature, imputed round-trip cost (IRC). This measure is based on the observation that several trades of identical volume within a brief span are indicative of a pre-matched arrangement where a dealer aligns a buyer with a seller. The difference between the highest and lowest prices in these trades represents the bid-ask spread and serves as an indicator of the bond's liquidity. In line with the literature, we use the entire bid-ask spread.[13] For corporate bonds, data is from Trade Reporting and Compliance Engine (TRACE). The same IRC measure can be constructed for municipal bonds using MSRB Municipal Securities Transaction Data.

[13] In practice, the seller may only incur a portion of the bid-ask spread. Nevertheless, scaling the bid-ask spread by a constant fraction will not change the relative magnitude of liquidity provision between debt and equity.

For the liquidation cost ϕ_j of Treasury bonds, we obtain the time series of bid-ask spreads of two-year, five-year, ten-year, and thirty-year Treasury bonds from Adrian, Fleming, Shachar and Vogt (2017) and Fleming and Ruela (2020). We interpolate the bid-ask spreads to Treasury bonds with other maturities. For the liquidation cost ϕ_j of stocks, we obtain the percent quoted spread (PQS) for each security from WRDS.

Panel (a) of Figure 3 shows the volume-weighted average of liquidation costs across different asset categories in our dataset. Corporate bonds exhibit the highest average liquidation costs at 43 basis points (bps), followed by municipal bonds with an average of 28 bps. Stocks have lower average liquidation costs of 12 bps, and Treasury bonds have the lowest, averaging at 2 bps. We note that transaction costs are a lower bound to liquidation costs. In practice, selling illiquid assets at short notice incurs price impact in addition to transaction costs. Nevertheless, both transaction costs and price impact are increasing in asset illiquidity, which is why the relative magnitudes of transaction costs are good proxies for relative liquidation costs across assets.

For asset classes that neither have bid-ask spreads nor transaction data available, such as loans, we extrapolate liquidation costs using their relative liquidity ratio with corporate bonds based on Chernenko and Sunderam (2022). Chernenko and Sunderam (2022) show that the cross-sectional relationship between mutual fund cash holdings and flow volatility reveals funds' expectations of their assets' future liquidity. They find that syndicated loans are perceived to be 4.8 times as illiquid as corporate bonds. We use this ratio to extrapolate the liquidity of corporate loans. For robustness, we also proxy for loan liquidation costs with one to four times the liquidation cost of high-yield corporate bonds. These results are presented in Section 4.3.

Finally, for asset classes without perceived relative liquidity ratios, such as agency debt, agency mortgage-backed securities (MBS), and asset-backed securities (ABS), we extrapolate liquidation costs using their relative liquidity ratio with corporate bonds based on repo haircuts from the New York Fed as in Bai, Krishnamurthy and Weymuller (2018).

Panel (b) of Figure 3 displays the average imputed liquidation costs for asset categories where both bid-ask spreads and transaction data are unavailable. Loans have the highest average liquidation costs at 215 bps, followed by ABS at an average of 57 bps. The lowest liquidation costs are for MBS at 16 bps and agency debt at 15 bps.

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 mutual funds, 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 note that our observed flows are net outflows that arise from gross outflows and inflows. The use of net outflows is consistent with our model in which net outflows lead to asset liquidations, depress contract payments, and ultimately affect liquidity provision per dollar (as in Definition 2). For the effect of netting gross outflows and inflows at the fund-level, please refer to Chernenko and Doan (2022).

Taken together, we construct the realized LPI for each intermediary i in each quarter, as in equation (2.2), 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 (2.3), 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.

3.3 Comparison with Existing Measures of Bank Liquidity Provision

Before proceeding, we compare the LPI to the two existing measures of bank liquidity provision—the Berger and Bouwman (2009) (BB) measure and the Liquidity Mismatch Index (LMI) developed by Bai, Krishnamurthy and Weymuller (2018). The LPI we develop complements these two measures that focus on banks. The key distinction is that the LPI can also be applied to demandable-equity issuing intermediaries like mutual funds, which is achieved through formalizing the effect of contract design and incorporating endogenous variation in investor flows.

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^A_{jt} and liability weights w^L_{kt} as

$$BB_t = \left(\frac{1}{2}\sum_{k\in L} w^L_{kt} - \frac{1}{2}\sum_{k\in IL} w^L_{kt}\right) - \left(\frac{1}{2}\sum_{j\in L} w^A_{jt} - \frac{1}{2}\sum_{j\in IL} w^A_{jt}\right), \tag{3.5}$$

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.[14] 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^A_{jt} and liability weights w^L_{kt} as

$$LMI_t = \sum_{j=0}^{J} w^A_{jt}(1 - \phi_{jt}) - \sum_{k=0}^{K} w^L_{kt}(m_{kt}), \tag{3.6}$$

where ϕ_j is the discount of asset j at time t when converted into cash at short notice,[15] and $w^L_{kt}(m_{kt})$ is a liquidity weight for each liability category k, which is a function of maturity m_{kt}.

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.

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

[14]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.

[15]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.

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.

In Internet Appendix D, we compute the LMI and BB measure for our sample period and compare them with the LPI. We find that the difference in variation between the LMI and the LPI mainly arise because the LPI captures liquidity provision while the LMI captures liquidity shortfall. For the BB measure, fluctuations are minimal because of fixed liability and asset side-weights.

4 Liquidity Provision by Banks and Mutual Funds

We first examine fund LPI in Section 4.1 and then present fund LPI in comparison to bank LPI in Section 4.2, with a number of robustness results in Section 4.3.

4.1 Fund LPI

We begin with analyzing liquidity provision in the cross-section of funds. We follow the procedure described in Section 3.1 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 4 plots the distribution of fund LPIs and Panel (a) of Table 2 provides summary statistics. Liquidity provision by the average fund is 21.7 bps per dollar, while funds at the first, second, and third quartile of the distribution provide 15.6, 21.9, and 28.8 bps of liquidity per dollar. To put these magnitudes into perspective, note that the average liquidation cost for corporate bonds in our sample is 43 bps. This implies that the amount of liquidity transformation to eliminate all liquidation costs for a portfolio of corporate bonds would be 43 bps. Relatively, our average fund LPIs are sizable at about half of this number. The gap arises mainly because funds hold other assets with liquidation costs below that of corporate bonds and also because funds cannot transform 100% of the illiquidity of their assets.

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

Internet Appendix B. Overall, fund LPIs remain similar with the average ranging between 21.4 to 21.7 bps 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.

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.

From Table 3, we find that lower cash ratios and more illiquid assets are associated with higher liquidity provision, all else equal. This result is consistent with Definition 2 and the comparative statics in Section 2.3, which show that the equilibrium portfolio share in the illiquid asset plays an important role in driving liquidity provision. Comparing the baseline results in columns (1) and (2) with those for fund equity with partial NAV striking in columns (3) and (4), we find that NAV striking renders fund LPI more sensitive to outflows. This is because the contract payment value is partially reduced in anticipation of outflows under NAV striking so that liquidity provision drops as outflows increase.

4.2 Bank LPI versus Fund 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 3.1 and then average over time at the bank level. The cross-sectional distribution of bank LPIs is shown in Figure 5. In the overall sample period, a dollar invested in the average bank provides 173.4 bps per dollar of liquidity, as demonstrated in Panel (b) of Table 2. In comparison, funds provide an economically significant amount of liquidity per dollar at 21.7/173.4=12.5% of that of banks. Overall, these results align with the comparative statics in Section 2.3 that bank debt generally provides more liquidity compared to mutual fund equity due to its more stable contract payments.

Estimating bank liquidity provision is generally challenging. Our LPI formula accounts for the uninsured portion of bank deposits, but deposit insurance and non-deposit liabilities may indirectly influence banks' run risk and portfolio decisions. As our findings in Section 2.3 show, indeed, bank debt with deposit insurance benefits from reduced run risk and allows the bank to hold a larger fraction of illiquid assets. Unfortunately, the ideal experiment of the same bank operating with and without deposit insurance does not exist. To take this challenge, we perform a simple test in this section to show that regulation does not fully explain the liquidity provision by debt-funded intermediaries. Our second test to take this challenge makes use of the 2016 Money Market Reform, which will be explained in Section 5.

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. The implicit assumption is that the relationship between bank LPI and the extent of deposit insurance is linear. We acknowledge that our results on bank liquidity provision may still contain partial effects of deposit insurance if the underlying relationship is nonlinear or if the perceived insurance applies beyond the insured deposit limit.

In all four columns of Table 4, 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 is 141.6 bps and that without insured deposits and non-deposit liabilities is 137.0 bps. 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. Banks' default risk and their asset choices are jointly determined in equilibrium, but all else equal, the results in columns (3) and (4) show that banks with more illiquid portfolios, lower cash buffers and lower default risk also have higher LPIs.

Finally, we examine realized fund versus bank liquidity provision over time and find that the gap has been narrowing. In Figure 6, we plot the quarterly average of bank- and fund-level LPIs from 2011Q1 to 2017Q4 weighted by asset size. We observe that liquidity provided by each dollar in bank deposits has dropped significantly, while liquidity provided by each dollar in fund shares has remained relatively constant. Magnitude-wise, the difference in liquidity provision between funds and banks has decreased from 206.5 bps per dollar in 2011Q1 to 136.7 bps per dollar in 2017Q4. While a full characterization of the narrowing gap between fund versus bank LPI is beyond the scope of this paper, we highlight the important role played by unconventional monetary policy and 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 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 fall in bank LPI. 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 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 experience the most pronounced decline in LPI. This finding is consistent with the interpretation that the

LCR moves commercial banks towards narrow banks which constrains liquidity provision and may have contributed towards the migration of liquidity provision to funds.

4.3 Robustness

First, we re-estimate fund LPI considering the liquidation order proposed by Jiang, Li and Wang (2021). Our baseline LPI measure assumes that funds follow a pecking order of liquidation by first selling the most liquid assets. In practice, managers may deviate from this benchmark and liquidate assets more evenly, as shown in Jiang, Li and Wang (2021). This practice lowers the liquidity provided because the average portfolio has a higher per unit liquidation cost than the most liquid asset in the portfolio. Indeed, our re-estimated fund LPIs in Table 5a drop to 15.4 bps when the proportional liquidation order is applied in high-volatility periods.

Given the importance of the liquidation cost of loans versus bonds in the comparison of liquidity provision between banks and funds, we conduct sensitivity analysis by re-estimating bank and fund LPI with loan liquidation costs scaled with the liquidation costs of high-yield bonds. The results are shown in Table 5b for funds and Table 6a for banks. When loan liquidation costs are one, two, three, and four times that of high-yield corporate bonds, the corresponding bank LPIs are 79.4, 116.3, 153.4, and 190.8 bps. The corresponding fund LPIs range between 21.3 and 21.9 bps, which is minimaly changed from the baseline because loans are a small fraction of fund portfolios. In all these cases, fund LPI remains economically significant but smaller in size than bank LPI.

Further, we re-estimate fund LPIs by letting the liquidation cost of municipal bonds be two times that of corporate bonds following Chernenko and Sunderam (2022). From the results in Table 5c, we see that fund LPIs is becomes larger at 31.9 bps, which strengthens the economic magitude of fund liquidity provision.

For banks, we also recalculate the LPI using lagged asset values for the expected portfolio value, as explained in Section 3.1. From the results in Table 6b, bank LPI becomes slightly higher at an average of 182.2 bps per dollar.

Another concern is that bank market power may reduce the actual amount of liquidity that depositors receive. 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 in Table 6c show that the resulting LPI decreases to 75.8 bps per dollar. If we subtract management fees from the fund contract payment, fund LPI would become slightly negative as shown in Table 5d. This is likely because funds not only provide liquidity to investors but also offer access to and pass through returns from bond markets.

Finally, we explore the determinants of realized bank and fund LPI. To this end, we estimate equations (4.1) and (4.2) using panel data and show the results in Internet Appendix Tables A1 and A2 in Internet Appendix E. Overall, the qualitative results resemble those in Tables 3 and 4, respectively. In the cross-section, more illiquid asset holdings improve liquidity provision, while larger outflows and higher default risk decrease liquidity provision.

5 Liquidity Provision by MMFs and the Money Market Reform

We further apply our LPI to shed light on liquidity provision by MMFs. This application is important in two aspects. First, MMFs transform a portfolio of Treasury bills and short-term debt to the financial sector into open-ended fund shares that provide an important source of liquidity to retail investors. While they are commonly compared to narrow banks because regulation requires them to hold short-term assets, the extent of their liquidity provision is not known.

At the same time, MMFs serve as a unique laboratory to study the capacity of debt versus equity in liquidity provision. There is no deposit insurance and implicit guarantees that might confound the estimates. Furthermore, the Money Market Reform in 2016 induced a switch from debt to equity funding for a subset of funds. More specifically, it required institutional prime and tax-exempt MMFs 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 that continued reporting a $1 fixed share price.[16] 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.

[16]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

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 and then declined after the reform, settling around pre-reform levels around the beginning of 2018. This trend is likely because institutional MMFs anticipated the need to meet heightened redemptions and converted more assets into cash ahead of time. Following the reform, cash declined as it was increasingly used up by investor redemptions that remained elevated for some time. These developments right around the implementation of the reform 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 funds were generally parallel to each other in the pre-period. In the post-period, the LPI of institutional MMFs experiences 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, we estimate

$$LPI_{jt} = \alpha + \beta_1 PostReform_t + \beta_2 InstitutionalFund_j + \beta_3 PostReform_t * InstitutionalFund_j + \epsilon_{jt}. \tag{5.1}$$

Column (1) of Table 7 shows the baseline results. We observe that before the reform, the LPIs for prime retail and institutional MMFs were 18.9 bps and $18.9 - 1.2 = 17.7$ bps, respectively. These numbers are below that of bank and fund LPIs because MMFs's investment mandate only allows them to invest in money market instruments of at most one year in maturity. While these relatively liquid asset holdings reduce run risk, they also limit the capacity of liquidity provision by raising the direct liquidation value of the underlying portfolio. In other words, the LPIs of MMFs are low because investors would already do quite well by holding and selling the underlying assets themselves in the absence of the intermediary.

From Table 7, we further see that 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 1-1.09/(18.93-1.22)=93.8% of their liquidity provision as they switch from fixed to floating NAVs, as shown from the baseline estimates in column (1). 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 at least 91.5% of their LPIs.

Our results in this section confirm that demandable equity provides a significant amount of liquidity compared to demandable debt, consistent with our findings from banks and mutual funds. Magnitude-wise, the gap between debt and equity in liquidity provision is smaller in the context of institutional MMFs than in the comparison between bank debt and bond mutual fund equity. One key reason is that restrictions on MMF's asset holdings constrain the difference in portfolio choices between institutions that fund using debt versus equity, which limits the difference in their liquidity provision. This finding is consistent with the theoretical comparative statics in Section 2.3, which show that the variation in liquidity provision by contract type is indeed reduced when the underlying assets are less illiquid. Therefore, the difference in liquidity provision uncovered in this section can be viewed as a lower bound to the difference in liquidity provision by demandable debt and equity when institutions' portfolio choices are unconstrained.

6 Swing Pricing and Liquidity Provision

Finally, we extend our framework to analyze liquidity provision by fund equity with swing pricing. We first shed light on the impact of swing pricing on fund liquidity provision in Section 6.1. We then construct a ready-to-use LPI for fund equity with swing pricing in Section 6.2 and compare liquidity provision with swing pricing to that by ETFs in Section 6.3. Taken together, our findings help inform the debate on whether swing pricing can effectively mitigate run risks without compromising the liquidity provision function of fund equity.

6.1 The Effect of Swing Pricing on Asset Portfolio and Liquidity Provision

Equity contracts with swing pricing allow funds to adjust their NAVs to incorporate outflow-induced liquidation costs. Formally, we model swing pricing under the unified framework in Section 2 by letting the cash payment at $t = 1$, $c_s(R, \lambda)$ depend not only on R but also on the number of agents redeeming at $t = 1$, λ. In this way, the outflow-induced liquidation costs will be fully incorporated into the end-of-day NAV and proportionally borne by all agents. We detail the NAV calculation under swing pricing in Appendix B, and then follow Proposition 1 to characterize liquidity provision by fund equity with swing pricing:

Proposition 2. *Given any equilibrium intermediary portfolio allocation (x, y), outflows λ, and economic fundamentals R, the LPI for fund equity with swing pricing is given by*

$$LPI_s = \begin{cases} \dfrac{x + y\beta(R)}{x + (1-\phi)y\beta(R)} - 1 & \lambda \leq \dfrac{x}{x + y\beta(R)}\,, \\ \dfrac{1}{1 - (1-\lambda)\phi} - 1 & \lambda > \dfrac{x}{x + y\beta(R)}\,, \end{cases} \tag{6.1}$$

where panic runs are eliminated in the sense that there is no first-mover advantage among investors and λ^* is unique for any given R.

Expression (6.1) suggests that the use of swing pricing allows fund equity to provide liquidity in a more continuous way. The first line of (6.1) shows that if cash is sufficient to meet redemptions at the end-of-day NAV, the fund deploys cash without adjusting its NAV. As more agents redeem and cash is used up, the fund continuously adjusts its end-of-day NAV downwards to incorporate the resulting liquidation costs, as shown in the second line of (6.1). Notably, the LPI for fund equity with swing pricing is always continuous in λ without the discontinuous jump induced by runs on fund equity. This is because 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. Figure 9 illustrates this comparison using the simple case of $\beta(R) = 1$.

Next, we compare the magnitude of liquidity provision by fund equity with and without swing pricing under the optimal portfolio allocation defined in Definition 2. This analysis sheds new light on the commonly perceived concern that less liquidity may be provided with swing pricing as funds swing the NAV of redeeming investors downwards.[17] We show that this argument is incomplete because it does not take into account the equilibrium effect on fund asset holdings. Formally, we have the following proposition after solving the intermediary's problem at $t = 0$.

Proposition 3. *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 3 points to to the effectiveness of swing pricing in mitigating mutual funds' financial stability risks without hurting their core function of liquidity provision. The intuition underlying Proposition 3 is as follows. Recall from Proposition 2 that swing pricing eliminates panic runs. Thus, late agents are more likely to stay until $t = 2$ with swing pricing, reducing the need for the fund to pre-maturely liquidate the illiquid asset at $t = 1$. Consequently, the fund will optimally hold less cash and a larger fraction of the illiquid asset after the adoption of swing pricing as long as it held some cash before the adoption of swing pricing. Proposition 3 thus provides a theoretical foundation for the empirical findings in Jin, Kacperczyk, Kahraman and Suntheim (2022) that mutual funds hold lower liquid buffers after the adoption of swing pricing.

Furthermore, a larger fraction of illiquid asset holdings implies that 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.[18]

[17] For example, the Investment Company Institute argues that swing pricing would harm investors in general, see https://www.ici.org/sec-swing-pricing. The US Chamber of Commerce is particular concerned about investors in retirement accounts, see https://www.uschamber.com/finance/the-secs-swing-pricing-proposal-could-hurt-your-retirement-account. Their concerns center around the risk of redeeming investors receiving lower returns than before due to increased transaction costs, price volatility, and complexity.

[18] Another way to understand the second sufficient condition of Proposition 3 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

6.2 Empirical Implementation of LPI for Fund Equity with Swing Pricing

Generalizing the LPI for fund equity with swing pricing in Proposition 1, we have

$$LPI_s = \frac{1}{1-\overline{\phi}} \cdot \underbrace{\frac{\sum_{j=0}^{J-1}(1-\phi_j)w_j + \sum_{j=J}^{N}(1-\phi_J)w_j}{1-(1-\lambda)\phi_J}}_{1-\text{swing factor}} - 1 \text{ when } \lambda_{J-1} < \lambda \leq \lambda_J, \tag{6.2}$$

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.[19] See derivations in Appendix C.3.

Estimating (6.2) requires observing fund asset composition and investor outflows in the presence of swing pricing. This data is not available for U.S. mutual funds because swing pricing has not been implemented in our sample period. However, the same formula can be applied to estimate fund LPI in other jurisdictions where swing pricing has been adopted.

We note that swing pricing in practice may come with constraints and complexities that require modifying the formulation in (6.2). First, funds in some jurisdictions may impose caps on the maximum swing factor.[20] In this case, (6.2) applies to cases where the swing factor is below the cap, while the swing factor can be set to the cap in all other cases. Second, some funds only adopt swing pricing after outflows reach a minimum threshold.[21] In these cases, (6.2) applies to cases after the outflow threshold is reached, while (3.2) applies to cases below the threshold.

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.

[19] A comparison with (3.2) helps to uncover the intuition underlying (6.2). When liquidity is provided, the LPI for fund equity with swing pricing differs from that without swing pricing by the swing factor. 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 liquidation costs up to the marginal asset J that is liquidated to meet redemptions.

[20] For investment funds in Luxembourg, for example, see https://www.alfi.lu/getattachment/8417bf51-4871-41da-a892-f4670ed63265/app_data-import-alfi-alfi-swing-pricing-survey-2022.pdf

[21] See https://www.bankofengland.co.uk/report/2021/liquidity-management-in-uk-open-ended-funds for investment funds in the UK, for example.

Finally, the swing factor in our formulation incorporates all liquidation costs that directly arise from redemptions at the fund level. 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), fund managers' compensation benchmarking (Feroli, Kashyap, Schoenholtz and Shin, 2014), and correlated asset sales by other funds (Falato, Goldstein and Hortacsu, 2021). In these settings, the swing factor would involve more inputs such as the overlap between funds' asset portfolio holdings to incorporate the full costs of redemptions. The swing factor of one fund may also depend on the policies of other funds (Capponi, Glasserman and Weber, 2020, 2022). We leave these considerations for future research.

6.3 Do ETFs implement Swing Pricing?

We finally examine whether fund liquidity provision with swing pricing can be effectively achieved through ETFs. In principle, the exchange-traded nature of ETFs allows investors to receive the market price when selling shares in secondary markets, which is reminiscent of the forward-looking nature of fund equity with swing pricing. Nevertheless, our analysis shows that the connection between ETFs and mutual funds with swing pricing is more subtle due to constraints to arbitrage.

We follow Koont, Ma, Pastor and Zeng (2024) in modeling ETFs. We consider a representative ETF that offers an equity contract, whose payment c_{ETF} at $t = 1$ depends on fundamentals R and the number of selling investors λ. A deep-pocketed, risk-neutral, representative authorized participant (AP) buys ETF shares from λ selling investors for a price of c_{ETF} and immediately redeems them in kind at the end of $t = 1$ for the underlying portfolio (x, y) with the ETF.[22] The AP holds the portfolio on its balance sheet until $t = 2$, incurs a quadratic balance sheet cost $\frac{1}{2}\psi s^2$ when holding s units of the illiquid asset, and then enjoys the realized returns of the portfolio at $t = 2$. This specification is motivated by the fact that APs for bond ETFs are typically bank dealers, which are subject to balance sheet costs due to regulation. We have the following result regarding the ETF price and LPI:

[22] As discussed in Koont, Ma, Pastor and Zeng (2024), ETFs can use custom baskets that may differ from their portfolio holdings to aid in AP arbitrage. Our focus, however, is not on this aspect of ETF basket design; instead, we focus on the role of ETFs in liquidity provision.

Proposition 4. *The ETF's market-clearing price at time 1 is given by*

$$c_{ETF}(R, \lambda) \,=\, x + yR - \psi y^2 \lambda\,, \tag{6.3}$$

with the LPI given by

$$LPI_{ETF} \,=\, \frac{x + yR - \psi y^2 \lambda}{x + (1-\phi) y \beta(R)} - 1\,. \tag{6.4}$$

The comparative analysis of LPI_{ETF} and LPI_s in (6.1), reveals several insights. First, ETFs avoid premature asset liquidation by leveraging the AP's balance sheet capacity to facilitate liquidity provision. This mechanism is supported by empirical evidence indicating that ETF mispricing is influenced by the balance sheet conditions of APs (e.g., Pan and Zeng, 2019). More generally, this finding is consistent with the intermediary-based asset pricing literature that highlights the role of dealer balance sheet constraints in determining asset prices and market liquidity (e.g., Du, Tepper and Verdelhan, 2018, He, Khorrami, and Song, 2022).

Second, the ETF price is inversely related to ψ, y, and λ. A higher ψ reflects increased costs impacting the AP's balance sheet, while a rise in y or λ signifies a greater need for balance sheet capacity to conduct effective arbitrage. In both instances, the resulting effect is a decrease in the ETF's price, which in turn reduces its liquidity provision at $t = 1$.

Finally, although the ETF price declines with the number of selling investors, it does not replicate the swing-pricing equilibrium outcome. As illustrated in the proof of Proposition 1, under fund equity with swing pricing, redeeming investors are offered a price defined by:

$$c_s(R, \lambda) = \begin{cases} x + y\beta(R) & \lambda \leq \dfrac{x}{x + y\beta(R)}\,, \\ \dfrac{x + (1-\phi)y\beta(R)}{1-(1-\lambda)\phi} - 1 & \lambda > \dfrac{x}{x + y\beta(R)}\,, \end{cases} \tag{6.5}$$

which significantly diverges from the equilibrium price of an ETF (6.3), despite both prices being dependent on R and λ. From an economic standpoint, ETFs do not fully neutralize the costs between investors who sell early and those who remain at $t = 1$ as effectively as swing pricing does because of AP balance sheet constraints, potentially leaving room for a first-mover advantage. In other words, replicating the swing pricing mechanism in ETFs would require a highly specific balance sheet cost function, distinct from the typical quadratic cost specification. This suggests that perfectly mirroring swing pricing outcomes in ETFs under conventional balance sheet cost specifications is unattainable, highlighting a fundamental difference between how ETFs and funds with swing pricing provide liquidity.

7 Conclusion

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).

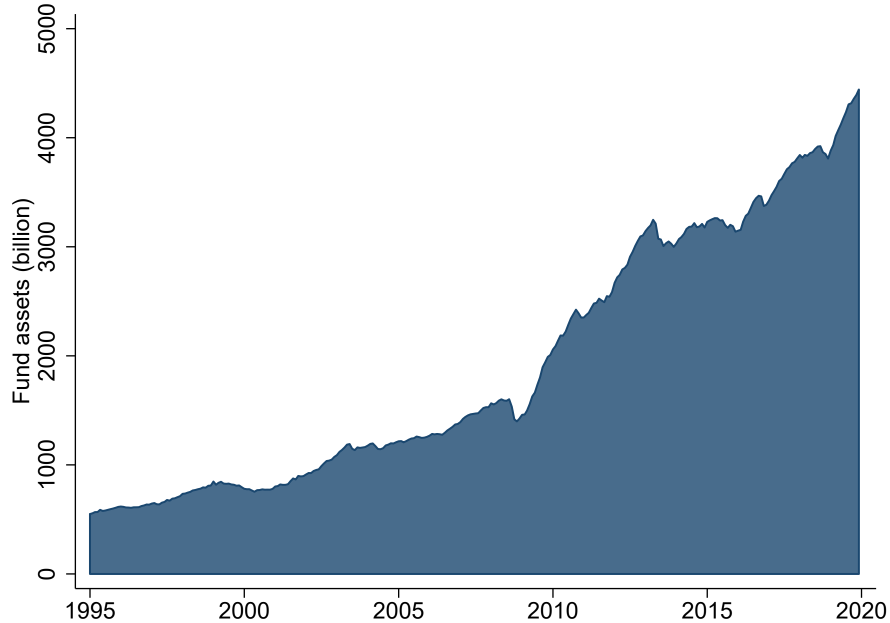
In this paper, we formally quantify liquidity provision by demandable fund equity and compare it to that of demandable bank debt. Liquidity provision stems from the pooling of idiosyncratic liquidity shocks at the intermediary level, which occurs independently of the contractual form of the intermediary's liabilities as long as they are redeemable at short notice. Based on the theory, we develop the 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 an economically significant amount of liquidity at around 12.5% of that by bank deposits.

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. In fact, fund liquidity provision may not necessarily be constrained if swing pricing is 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.

Our LPI can be generally applied to measure liquidity provision by demandable debt- and equity-issuing intermediaries. If swing pricing has been implemented, one could apply the LPI specifications with and without swing pricing to empirically estimate the effect of swing pricing on liquidity provision. Another promising avenue for future work would be to compare and contrast the LPI of different institutions under different economic conditions over a longer time period to understand their relative stability in liquidity provision.

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.



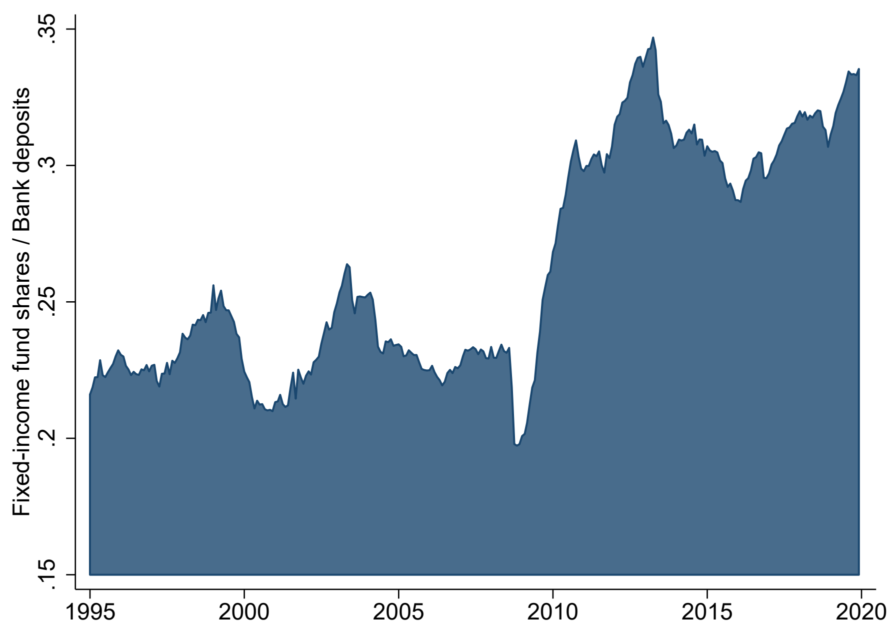
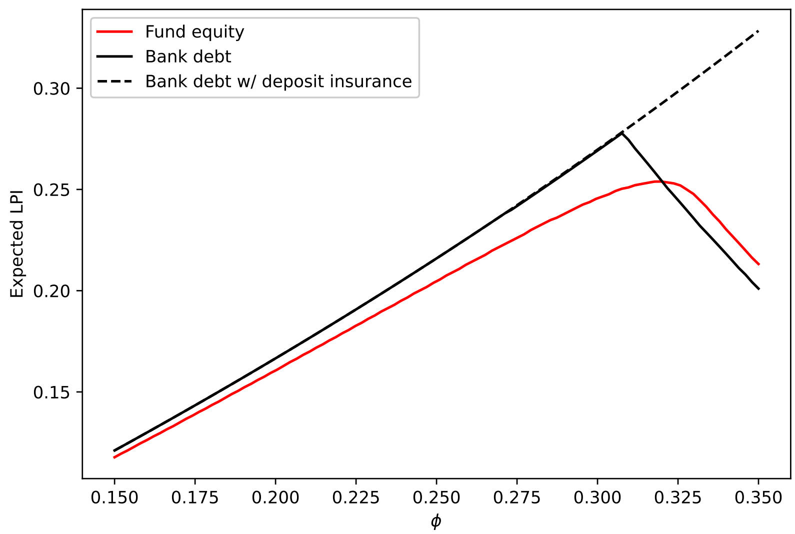


Figure 2: LPI and Portfolio Choice: Which Intermediary Provides More Liquidity

This graph depicts the level of expected LPIs (upper panel) and the optimal share of the illiquid asset y (lower panel) against liquidation cost ϕ. The solid black, dashed black, solid red, and red dashed lines represent bank debt, bank debt with deposit insurance, fund equity without swing pricing, and fund equity with swing pricing, respectively. The functional form and parameter choices follow Davila and Goldstein (2022). Investors have isoelastic utility with an elasticity of intertemporal substitution of $1/\gamma$, where $\gamma = 1.5$. The proportion of early investors is $\pi = 0.3$. Asset fundamentals R follow an exponential distribution with parameter $\eta = 5$, and the function $\beta(R)$ is defined as $\beta(R) = \frac{1}{2}(1 + R)$. The sunspot probability is $q = 0.3$.

(a) LPIs against Liquidation Cost ϕ



(b) Illiquid Asset Share y against Liquidation Cost ϕ

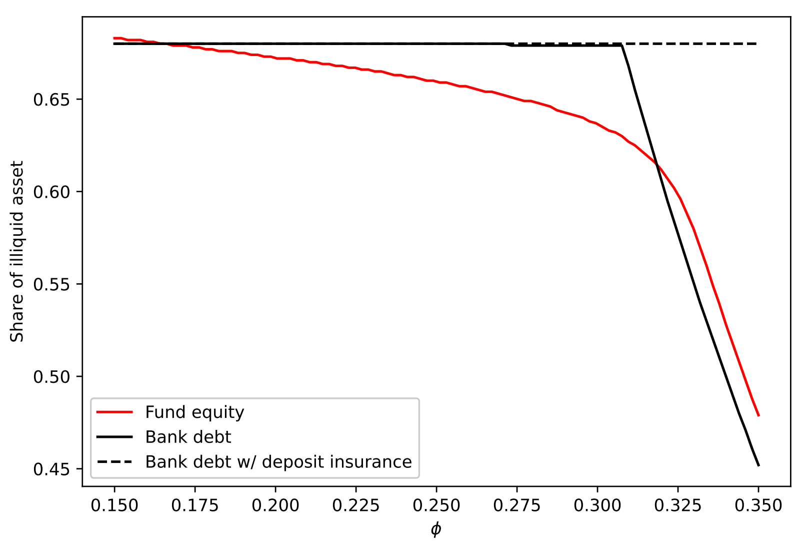
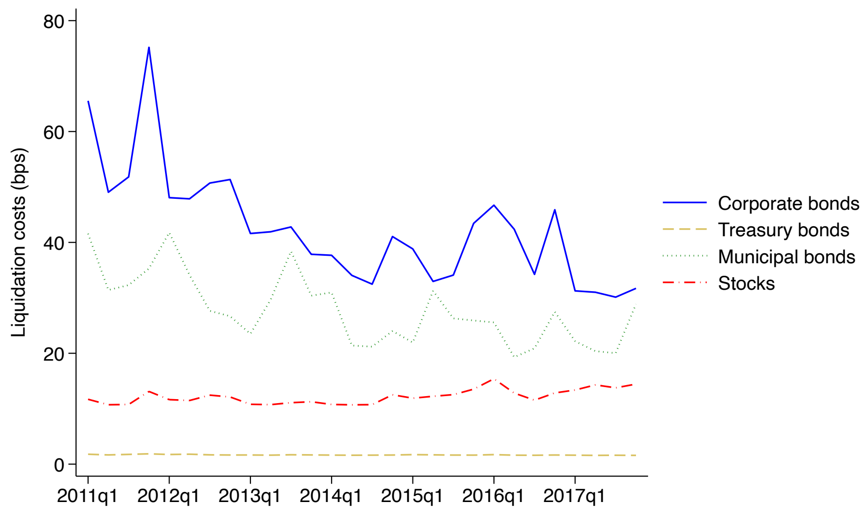


Figure 3: Liquidation Costs of Major Asset Classes

This graph plots the liquidation costs for different asset categories over time. Liquidation costs presented in panel (a) are measured by the average bid-ask spreads, transaction volume-weighted for individual security. The bid-ask spreads for corporate and municipal bonds are constructed from TRACE. The bid-ask spreads of 10-year Treasury bonds are obtained from Adrian, Fleming, Shachar and Vogt (2017) and Fleming and Ruela (2020). The bid-ask spreads of stocks are obtained from WRDS. Liquidation costs presented in panel (b) are imputed using the average liquidity of corporate bonds based on the relative liquidity ratio between asset classes in Chernenko and Sunderam (2022) and the collateral haircuts in repo markets used in Bai, Krishnamurthy and Weymuller (2018).

(a) Assets with Transaction Data



(b) Assets without Transaction Data

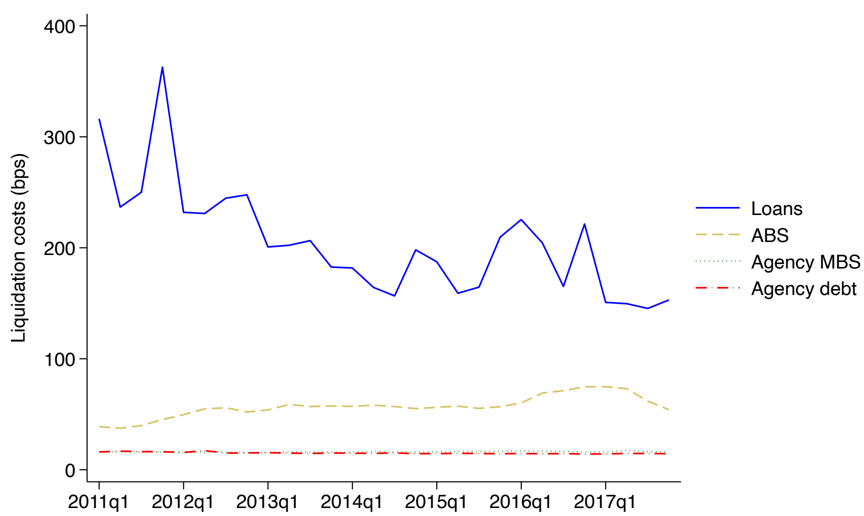


Figure 4: Fund Liquidity Provision in the Cross-Section

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. LPIs are expressed in bps.

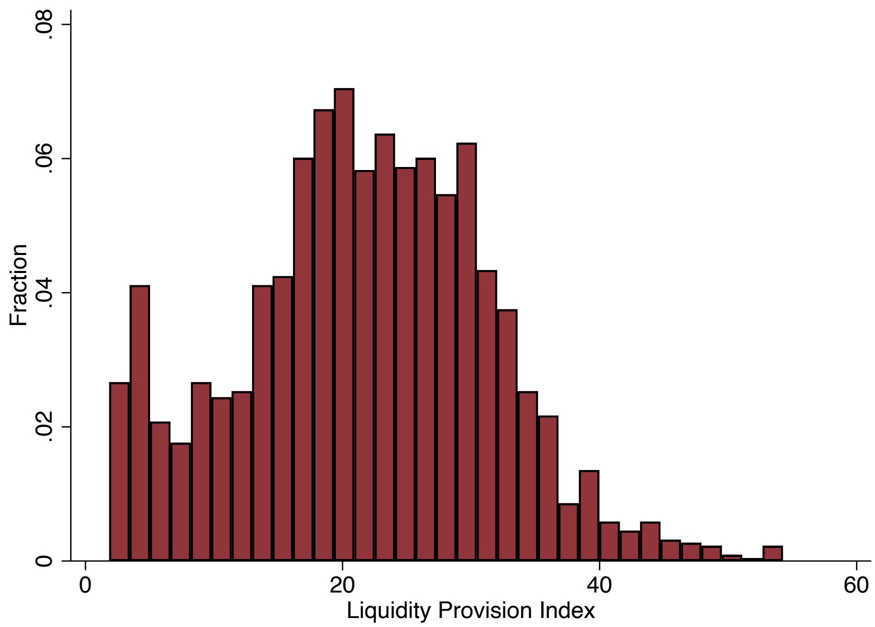


Figure 5: Bank Liquidity Provision in the Cross-Section

This figure 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. LPIs are expressed in bps.

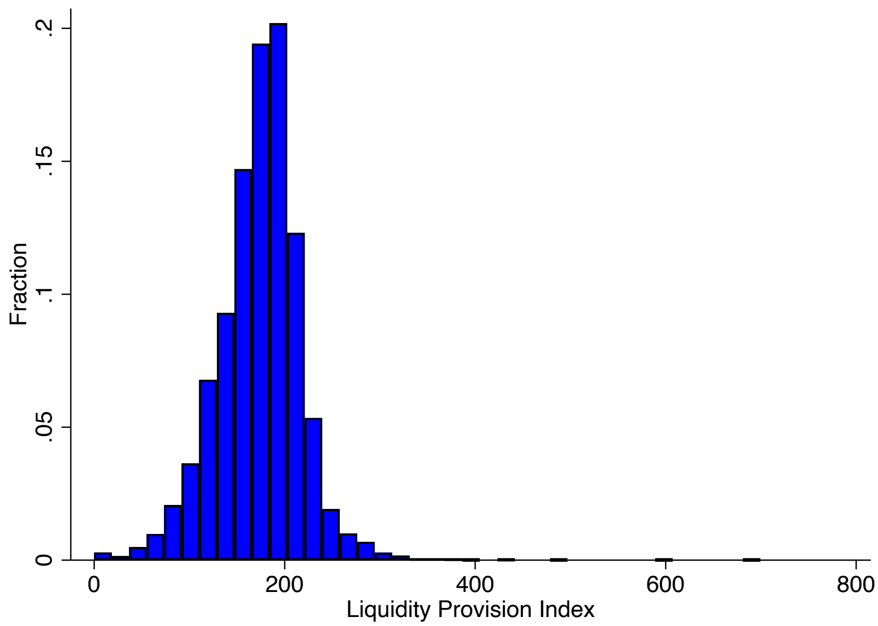


Figure 6: Bank and Fund Liquidity Provision over Time

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. LPIs are expressed in bps.

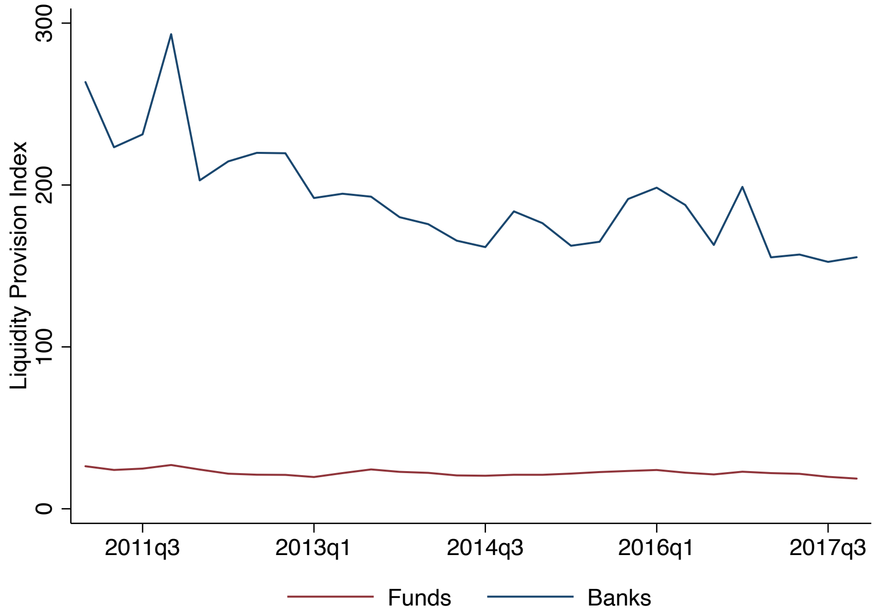
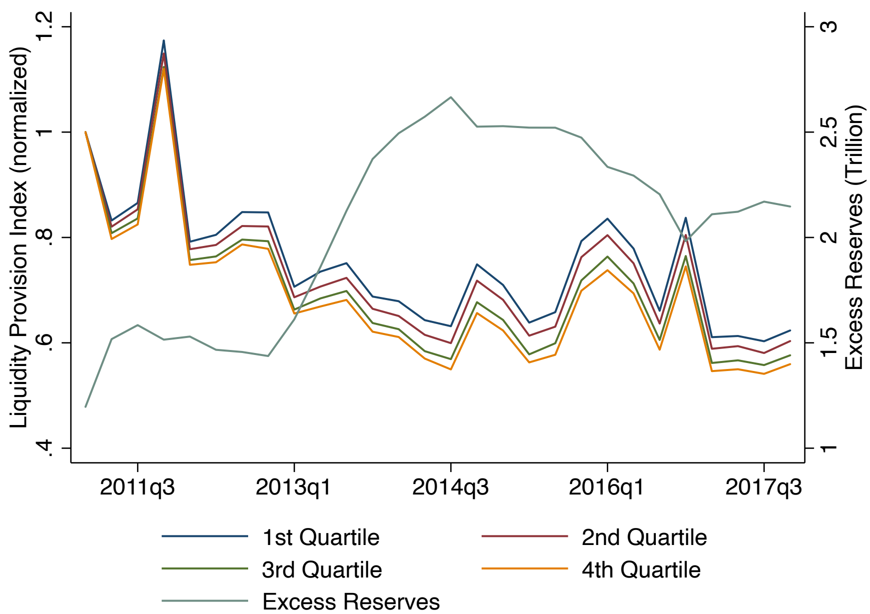


Figure 7: Bank Liquidity Provision, Excess Reserves, and Liquidity Regulation

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

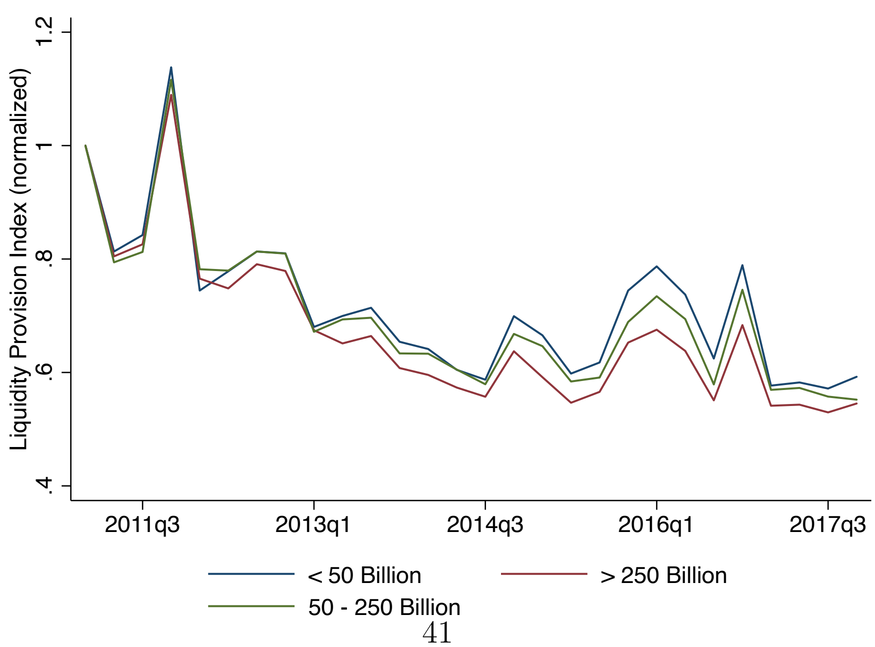
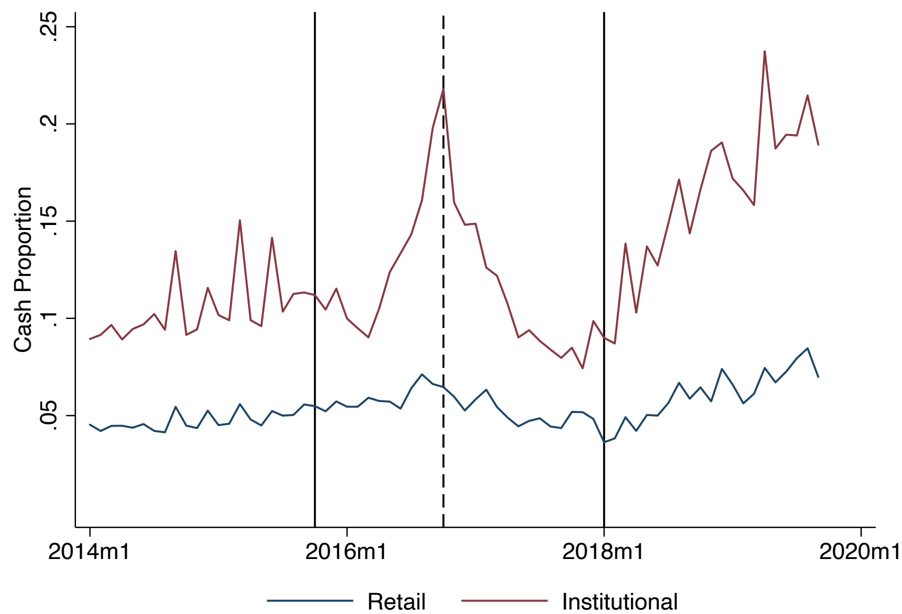


Figure 8: MMF Liquidity Provision

Panel (a) plots the average proportion of cash holdings of institutional and retail prime and tax-exempt MMFs from January 2014 to September 2019. Panel (b) plots the average LPIs of institutional and retail prime and tax-exempt MMFs from January 2014 to September 2019. LPIs are expressed in bps. 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. LPIs are expressed in bps.

(a) Cash in MMF Holdings



(b) Liquidity Provision Index

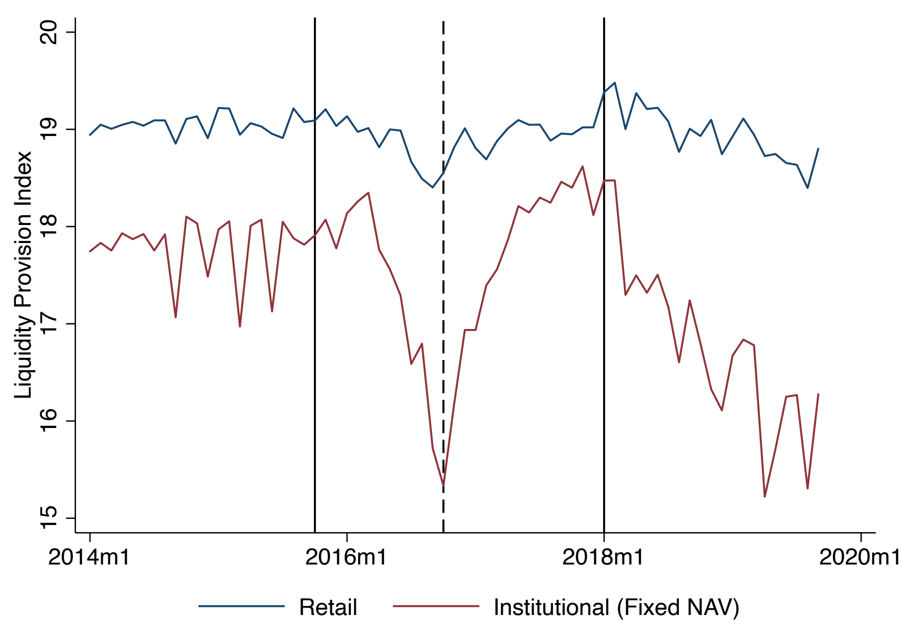


Figure 9: LPI for Fund Equity with and without Swing Pricing

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.

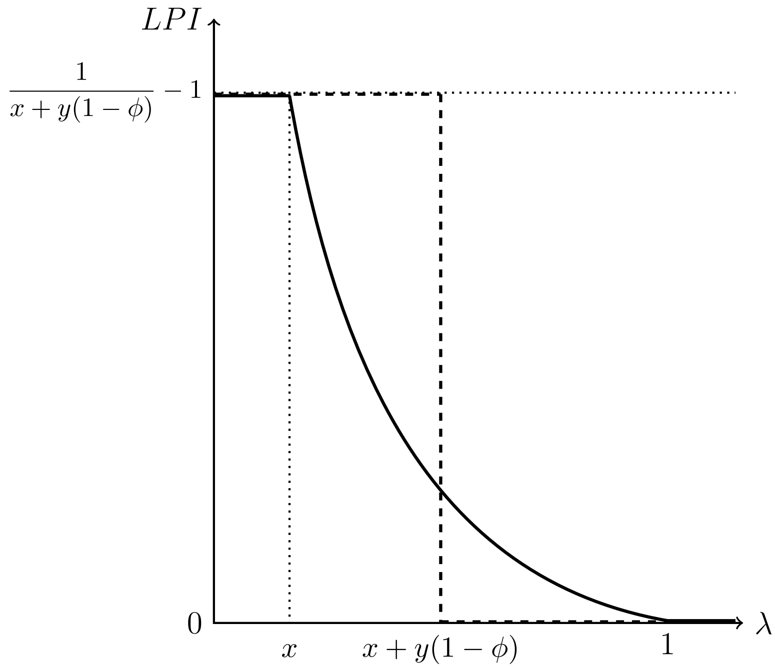


Table 1: Summary Statistics

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

(a) Funds

	mean	sd	p25	p50	p75
Cash	3.30	5.10	0.75	1.91	3.78
Treasuries	12.26	20.33	0.00	1.29	18.14
Agency Debentures	2.78	8.95	0.00	0.00	1.02
Agency MBS/CMO	5.79	12.21	0.00	0.00	5.03
Money Market	0.89	3.72	0.00	0.02	0.56
Muni	29.35	43.88	0.00	0.57	94.09
Corporate Bonds	32.06	32.99	0.01	26.27	57.74
CMO/ABS	5.59	10.03	0.00	0.24	7.67
Equities	7.60	18.68	0.06	1.80	5.60
Outflow	0.00	1.00	-0.62	-0.26	0.30

(b) Banks

	mean	sd	p25	p50	p75
Cash	11.66	9.61	5.63	9.10	14.58
Treasuries	0.62	2.60	0.00	0.00	0.17
Agency Debentures	5.73	7.44	0.75	3.19	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	6.30	7.83	0.45	3.47	9.47
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
Loans	60.94	15.85	52.28	63.41	72.40
Fixed Assets	5.56	3.73	3.40	5.00	6.89

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 fund LPI and Panel (b) shows bank LPI. LPIs are expressed in bps.

(a) Funds

	mean	sd	p25	p50	p75
LPI	21.7	9.7	15.6	21.9	28.6
LPI (10% NAV Striking)	21.7	9.7	15.5	21.9	28.5
LPI (20% NAV Striking)	21.7	9.7	15.5	21.9	28.5
LPI (30% NAV Striking)	21.6	9.6	15.5	21.8	28.5
LPI (40% NAV Striking)	21.6	9.6	15.5	21.7	28.4
LPI (50% NAV Striking)	21.5	9.6	15.5	21.7	28.4
LPI (60% NAV Striking)	21.5	9.6	15.5	21.7	28.3
LPI (70% NAV Striking)	21.5	9.5	15.4	21.7	28.2
LPI (80% NAV Striking)	21.4	9.5	15.4	21.6	28.2
LPI (90% NAV Striking)	21.4	9.5	15.4	21.6	28.1

(b) Banks

	mean	sd	p25	p50	p75
LPI	173.4	44.1	149.0	177.1	199.5

Table 3: Determinants of Fund LPI

This table shows the relationship between fund LPI and various fund characteristics, including average fund outflow, cash ratio, asset illiquidity, log asset size, log of fund age, retail fund indicator, and expense ratio. Columns (1) and (2) show the results for fund LPI without adjustments and columns (3) and (4) show the results for fund LPI with partial NAV striking. LPI and all explanatory variables are averaged over the sample period from 2011 to 2017. Explanatory variables are standardized. LPIs are expressed in bps.

	LPI		LPI (NAV Striking)	
	(1)	(2)	(3)	(4)
Outflow	0.12	0.07	-0.27***	-0.33***
	(0.08)	(0.08)	(0.07)	(0.08)
Cash Ratio	-5.40***	-5.39***	-5.18***	-5.17***
	(0.08)	(0.08)	(0.07)	(0.07)
Asset Illiquidity	7.27***	7.27***	7.12***	7.12***
	(0.07)	(0.08)	(0.07)	(0.07)
Expense Ratio	0.31***	0.25***	0.31***	0.27***
	(0.08)	(0.08)	(0.07)	(0.08)
Retail		0.30		0.19
		(0.25)		(0.24)
Age		0.34***		0.37***
		(0.08)		(0.08)
Asset Size		-0.14*		-0.15**
		(0.08)		(0.08)
Constant	21.74***	21.57***	21.42***	21.31***
	(0.07)	(0.16)	(0.07)	(0.15)
Observations	1,928	1,928	1,928	1,928
Adjusted R2	0.89	0.90	0.90	0.90

Table 4: Determinants of Bank LPI

This table shows the relationship between bank LPI and various bank characteristics, including insured deposit ratio, non-deposit liabilities ratio, default probability, cash ratio, asset illiquidity, and log asset size. Bank LPI and all explanatory variables are averaged over the sample period from 2011 to 2017. Explanatory variables except insured deposit ratio and non-deposit liabilities ratio are standardized for easier interpretation. LPIs are expressed in bps.

	LPI			
	(1)	(2)	(3)	(4)
Insured Dep. Ratio	37.63***	39.53***	19.24***	9.74***
	(4.75)	(4.81)	(3.87)	(1.60)
Non-deposits Liab.		18.52**	-14.87**	-21.87***
		(7.64)	(6.16)	(2.31)
Asset Illiquidity			26.33***	28.14***
			(0.41)	(0.15)
Default Prob				-8.80***
				(0.15)
Cash Ratio				-31.22***
				(0.16)
Asset Size				1.48***
				(0.18)
Constant	141.64***	137.04***	159.59***	168.75***
	(4.04)	(4.46)	(3.60)	(1.44)
Observations	7,545	7,545	7,545	7,545
Adjusted R2	0.01	0.01	0.36	0.91

Table 5: Fund LPI (Robustness)

This table provides summary statistics of fund LPI under several alternative specifications. We report moments of the cross-sectional distribution after averaging LPI at the fund level. Panel (a) shows fund LPI adjusted for the order of liquidation in Jiang, Li and Wang (2021). Panel (b) shows fund LPI assuming that loan liquidation costs are one to four times that of high-yield bonds. Panel (c) shows fund LPI assuming that municipal bond liquidation costs are two times that of corporate bonds. Panel (d) shows fund LPI net of fees. LPIs are expressed in bps.

(a) Funds (JLW Adjustment)

	mean	sd	p25	p50	p75
LPI	15.4	7.1	11.0	15.6	20.0

(b) Funds (Alternate Loan Liquidation Cost)

	mean	sd	p25	p50	p75
LPI (HY1)	21.3	9.3	15.5	21.5	28.0
LPI (HY2)	21.3	9.3	15.6	21.6	28.1
LPI (HY3)	21.8	9.7	15.6	22.0	28.6
LPI (HY4)	21.9	9.9	15.7	22.0	28.7

(c) Funds (Alternate Municipal Bond Liquidation Cost)

	mean	sd	p25	p50	p75
LPI	31.9	19.5	17.1	27.5	54.2

(d) Funds (Net of Fees)

	mean	sd	p25	p50	p75
(mean) nlpi	21.8	9.6	15.9	21.9	28.4

Table 6: Bank LPI (Robustness)

This table provides summary statistics of bank LPI under several alternative specifications. We report moments of the cross-sectional distribution after averaging LPI at the fund or bank level. Panel (a) shows bank LPI assuming that loan liquidation costs are two times that of high-yield bonds. Panel (b) shows bank LPI with lagged assets. Panel (c) shows bank LPI net of fees and expenses. LPIs are expressed in bps.

(a) Banks (Alternate Loan Liquidation Cost)

	mean	sd	p25	p50	p75
LPI (HY1)	79.4	27.3	64.2	77.4	90.9
LPI (HY2)	116.3	32.2	98.7	116.9	132.6
LPI (HY3)	153.4	39.3	132.0	156.3	176.3
LPI (HY4)	190.8	47.6	164.5	196.0	220.6

(b) Banks (Lagged Assets)

	mean	sd	p25	p50	p75
LPI	209.7	237.6	125.0	170.6	234.3

(c) Banks (Net of Fees)

	mean	sd	p25	p50	p75
(mean) nlpi	75.8	52.2	51.3	77.298	101.7

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. LPIs are expressed in bps.

	(1)	(2)	(3)	(4)
	LPI	LPI	LPI	LPI
Post Reform	-0.19	0.23	-0.29	-0.30*
	[0.16]	[0.14]	[0.18]	[0.17]
Institutional Fund	-1.22***	-1.20***	-1.22***	-1.22***
	[0.19]	[0.19]	[0.19]	[0.19]
Post Reform * Institutional Fund	-1.09***	-1.18***	-1.47***	-1.30***
	[0.27]	[0.24]	[0.28]	[0.28]
Constant	18.93***	18.93***	18.93***	18.93***
	[0.12]	[0.12]	[0.12]	[0.12]
Observations	1237	1153	1213	1234
Adj. R-squared	0.09	0.09	0.12	0.10

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A Proofs

Proof of Lemma 1. 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. ∎

Proof of Proposition 1. We first calculate the LPI 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 (2.4).

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 (2.4).

We then similarly calculate the LPI for bank debt.

CASE 2.1. 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 (2.5).

CASE 2.2. 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 (2.5). ∎

Proof of Proposition 2. First, we show that fund equity eliminates panic runs. 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 (B.2) and (B.3) give two conditions to calculate NAV_1:

$$\begin{aligned} NAV_1(\lambda) &= x + (y - \phi l)\beta(R) && \text{(A.2)} \\ &= \frac{x + (1-\phi)l\beta(R)}{\lambda}. && \text{(A.3)} \end{aligned}$$

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:

$$NAV_2(\lambda) = \frac{R}{\beta(R)}(x + (y - \phi l)\beta(R)),$$

which combined with (A.2) immediately leads to

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

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.

We then can calculate the LPI for fund equity with swing pricing. We still consider two cases.

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 $c_s(R, \lambda) = x + y\beta(R)$. Applying Definition 2 yields the first line of (6.1).

CASE 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 (B.2) and (B.3). Solving (B.2) and (B.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 (6.1). ∎

Proof of Proposition 3. Following the 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.[23] We establish the result for the case of $\pi = 0$ and $\phi = 1$, 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

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

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

$$0 = \int_{[1,+\infty)} (-qu'(1 - y) + (1 - q)u'(1 - y + yR)(R - 1))\, dG(R)\,. \tag{A.7}$$

When $y = 1$, $\lim_{y \to 1} u'(1 - y) = \infty$, while the other term in the right hand side of (A.7), that is, $(1 - q)u'(1 - y + yR)(R - 1)$, is 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 $y_f^* < 1$.

[23] 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 3 do not depend on the magnitude of q.

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 (2.3) 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 (6.1) 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 (2.4) in Proposition 1. ∎

Proof of Proposition 4. Consider the AP's profit maximization problem:

$$\max_{\lambda} \Gamma(\lambda) \equiv (x + yR - c_{ETF})\,\lambda - \frac{1}{2}\psi\,(y\lambda)^2\,. \tag{A.12}$$

Here, the first term in equation (A.12) captures the AP's expected arbitrage profit. Specifically, after buying λ ETF shares from λ selling investors at the price of c_{ETF} per share, the AP exchanges these shares for λ units of the ETF redemption basket, which is the portfolio (x, y) in our stylized model and has a time-2 payoff is of $x + yR$. The AP's profit per ETF share is therefore $x + yR - c_{ETF}$, yielding the first term. The second term in equation (A.12) reflects the AP's balance sheet cost associated with carrying y units of the illiquid asset for each of the λ ETF shares redeemed.

Taking the first-order condition with respect to λ yields:

$$x + yR - c_{ETF} - \psi y^2 \lambda = 0\,. \tag{A.13}$$

Solving for λ and applying the market clearing condition, we immediately get the equilibrium ETF price in equation (6.3). We then apply the definition of the LPI in Definition 2, which gives the equilibrium LPI for the ETF as in equation (6.4), concluding the proof. ∎

B Fund Equity with Swing Pricing: NAV Calculation

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:

$$c_s(R, \lambda) = x + y\beta(R)\,, \text{ if } x \geq \lambda(x + y\beta(R))\,, \tag{B.1}$$

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 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:

$$c_s(R, \lambda) = x + (y - \phi l)\beta(R)\,, \text{ if } x < \lambda(x + y\beta(R))\,, \tag{B.2}$$

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:

$$\lambda c_s(R, \lambda) = x + (1 - \phi) l\beta(R)\,, \text{ if } x < \lambda(x + y\beta(R))\,. \tag{B.3}$$

The solution to equations (B.2) and (B.3) pins down $c_s(R, \lambda)$ when $x < \lambda(x + y\beta(R))$.

C General LPI Derivation under Multiple Assets

C.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).

C.2 Bank Debt

Define

$$w_j' = \frac{\mathbb{E}[y_j\beta_j(R)]}{\sum_{j=0}^{N} y_j\beta_j(R)}\,. \tag{C.1}$$

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 (C.1) and applying Definition 2 yield the first line of (3.4).

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 (C.1) and applying Definition 2 yield the second line of (3.4).

C.3 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:

$$\sum_{j=0}^{J}(1-\phi_j)y_j\beta_j(R) = \lambda_J\left(\sum_{j=0}^{J}(1-\phi_j)y_j\beta_j(R) + \sum_{j=J+1}^{N} y_j\beta_j(R)\right), \tag{C.2}$$

where the left-hand side of (C.2) 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 (C.2) 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 (C.2), 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

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

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

$$\lambda NAV_1 = \sum_{j=0}^{J-1}(1-\phi_j)y_j\beta_j(R) + (1-\phi_J)l_J\beta_J(R). \tag{C.4}$$

Solving the system of equations (C.3) and (C.4) gives NAV_1 as a function of λ, and then using the definition of portfolio weight (3.1) and applying Definition 2 yields (6.2).

Internet Appendix for

Bank Debt, Mutual Fund Equity and Swing Pricing 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., a 40% liquidation discount). 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 (2.5) 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 (2.5) 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 conduct the numerical comparative statics in Section 2 and perform several additional tests in Section 4.

B Fund Equity with Partial NAV Striking

We extend our baseline model to accommodate the potential for mutual funds to partially strike their NAVs without adopting swing pricing. 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

$$NAV_1 = x + (y - \mu\phi l)\beta(R)\,, \tag{B.1}$$

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 5. *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*

$$LPI_{f;\mu} = \begin{cases} \dfrac{x + y\beta(R)}{x + y(1-\phi)\beta(R)} - 1 & \lambda \leq \dfrac{x}{x + y\beta(R)}\,, \\ \dfrac{1}{1 - (1 - \mu\lambda)\phi} - 1 & \dfrac{x}{x + y\beta(R)} < \lambda \leq \dfrac{x + y(1-\phi)\beta(R)}{x + y(1-\mu\phi)\beta(R)}\,, \\ 0 & \lambda > \dfrac{x + y(1-\phi)\beta(R)}{x + y(1-\mu\phi)\beta(R)}\,. \end{cases} \tag{B.2}$$

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.

Proof of Proposition 5. We first derive the LPI formula in (B.2).

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 (B.2).

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 (B.1), where l and NAV_1 are the solutions to equations (B.1) and (B.3) below:

$$\lambda NAV_1 = x + (1-\phi)l\beta(R)\,. \tag{B.3}$$

Solving (B.1) and (B.3) 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 (B.2).

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 (B.2).

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

$$\Delta(1,1) = x + (1-\phi)y\beta(R) - 0 > 0\,,$$ [2]

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. ∎

The economic insights underlying Proposition 5 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 (B.2) depends on the same economic observables as those presented in the three LPI formulas (2.4), (6.1), and (2.5) in Proposition 1. Proposition 5 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 further strengthens Lemma 1: even if a fund partially strikes

[2] 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.

its NAV, panic runs may still arise unless the fund NAV fully incorporates liquidation costs under full swing pricing.

Generalizing (B.2) in Proposition 5, we derive the LPI of fund equity with partial NAV striking as:

$$LPI_{f;\mu} = \begin{cases} \dfrac{1}{1-\overline{\overline{\phi}}} - 1 & \lambda \le \lambda_0 \\ \dfrac{1}{1-\overline{\overline{\phi}}} \dfrac{\sum_{j=0}^{J-1}(1-\mu\phi_j - (1-\mu)\phi_J)w_j + \sum_{j=J}^{N}(1-\phi_J)w_j}{1-(1-\mu\lambda)\phi_J} - 1 & \lambda_{J-1} < \lambda \le \lambda_J \\ 0 & \lambda > \lambda_N \end{cases} \tag{B.4}$$

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

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

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.4) as we did for the LPI for fund equity with swing pricing (6.2). 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.4), consider three exhaustive cases. First, when $y_0 \ge \lambda \sum_{j=0}^{N} y_j\beta_j(R)$, 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.4).

Second, when $y_0 < \lambda \sum_{j=0}^{N} y_j\beta_j(R)$ and $\sum_{j=0}^{N}(1-\phi_j)y_j\beta_j(R) \ge \lambda \sum_{j=0}^{N}(1-\mu\phi_j)y_j\beta_j(R)$, 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:

$$\sum_{j=0}^{J}(1-\phi_j)y_j\beta_j(R) = \lambda_J \left(\sum_{j=0}^{J}(1-\mu\phi_j)y_j\beta_j(R) + \sum_{j=J+1}^{N} y_j\beta_j(R) \right), \tag{B.5}$$

where the left-hand side of (B.5) 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.5) 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.5), 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

$$NAV_1 = \sum_{j=0}^{J-1}(1-\mu\phi_j)y_j\beta_j(R) + (y_J - \mu\phi_J l_J)\beta_J(R) + \sum_{j=J+1}^{N} y_j\beta_j(R)\,, \tag{B.6}$$

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

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

Solving the system of equations (B.6) and (B.7) gives NAV_1 as a function of λ, and then using the definition of portfolio weight and applying Definition 2 yields the second line of (B.4).

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 and applying Definition 2 yields the third line of (B.4).

C Data Appendix

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. Internet Appendix Table A1 provides a detailed mapping between balance sheet variables and our asset categories. We remove ETFs and index funds to obtain a sample of actively managed open-end fixed-income funds.

For the liquidation cost ϕ_j of corporate bonds, we use the imputed round-trip cost (IRC), a standard transaction-based liquidity measure in the corporate bond literature. This measure captures the difference between the highest and lowest prices in a set of matched trades, which reflects the bond's bid-ask spread. Specifically, several trades of identical volume within a brief time frame suggest a pre-arranged agreement between a buyer and seller via a dealer. Following the literature, we use one day as the time frame to estimate IRC. The IRC for a set of trades is computed as:

$$IRC = \frac{P^{max} - P^{min}}{P^{min}},$$

where P^{max} and P^{min} represent the maximum and minimum prices in a round-trip trade. We calculate the average IRC per bond in each quarter. If a bond has a missing IRC in a quarter, we impute its IRC using the average IRC of bonds in the same rating (e.g. BB+) and maturity (e.g., 5 year) bucket in that quarter.

For municipal bonds, we compute the IRC similarly to corporate bonds, using data from the MSRB Municipal Securities Transaction Data. For bonds with missing IRC values, we impute the IRC using the weighted average of municipal bonds based on their market values. As a robustness check, we also proxy municipal bond liquidation costs as two times the IRC of corporate bonds following Chernenko and Sunderam (2022). The weighted average IRC for municipal bonds is computed for each fund-quarter observation.

The liquidation cost ϕ_j of Treasury bonds is derived from the time series of bid-ask spreads for Treasury securities with maturities of two, five, ten, and thirty years, based on data from Adrian, Fleming, Shachar and Vogt (2017) and Fleming and Ruela (2020). Spreads for other maturities are interpolated from the available data points using a linear interpolation. These bid-ask spreads are then merged with the mutual fund holdings of Treasury bonds, organized by maturity buckets of one year interval. The weighted average Treasury bid-ask spread is computed based on the holdings for each fund-quarter observation.

For stocks, we compute the percent quoted spread (PQS) for each security using data from WRDS. The PQS is calculated on a daily basis for each stock. Since equity holding by bond funds is typically quite small, we aggregate the stock-level PQS into a market-cap-weighted average over the universe of stocks. The daily PQS is averaged over the quarter to produce the quarterly PQS, which is then applied at the asset class level to the stock holdings of each bond fund.

For asset classes without direct transaction data, such as loans, we extrapolate liquidation costs using relative liquidity ratios. Chernenko and Sunderam (2022) demonstrate that syndicated loans are perceived to be 4.8 times as illiquid as corporate bonds. We use this ratio to estimate the liquidity of loans held by funds. As a robustness check, we also apply proxies where loan liquidation costs are estimated at one to four times the IRC of high-yield corporate bonds.

Finally, for asset classes such as agency debt, agency mortgage-backed securities (MBS), and asset-backed securities (ABS), where direct liquidity measures are unavailable, we use repo haircuts from the New York Fed as in Bai, Krishnamurthy and Weymuller (2018). These haircuts are used to scale the liquidation costs of corporate bonds to approximate the liquidity costs of these other asset classes. For instance, the liquidation cost of the ABS of a fund is imputed as the liquidation cost of its corporate bond holdings, scaled by the ratio of haircuts between these two assets in the New York Fed repo data series. These scaled liquidity costs are then applied to the relevant bond fund holdings for each asset class.

The construction of liquidation costs for banks is similar to that for funds. Since bank call reports only contain asset class-level holding shares, we use the market-level IRC as shown in Figure 3 as the liquidation cost for corporate and municipal bonds held by banks. For Treasury bonds held by banks, we use the bid-ask spreads of ten-year Treasury bonds as the liquidation cost. Banks' equity holdings are also quite small so we aggregate the stock-level PQS into a market-cap-weighted average over the universe of stocks. For bank loans, we also extrapolate liquidation costs using relative liquidity ratios by Chernenko and Sunderam (2022). We use the same repo haircuts from the New York Fed to scale the liquidation costs of corporate bonds to approximate the liquidity costs for agency debt, agency mortgage-backed securities (MBS), and asset-backed securities (ABS). Finally, given that banks' fixed assets are typically not qualified as collateral to obtain repos, we assign a haircut of 100%, and use it to scale the liquidation costs of corporate bonds to approximate the liquidity costs of banks' fixed assets.

Please also refer to Internet Appendix Table A4 and A5 at the end of the Internet Appendix for a breakdown of liquidation costs for mutual funds and banks, respectively.

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	

D Empirical Comparison with Other Liquidity Measures

We replicate the Liquidity Mismatch Index (LMI) by Bai, Krishnamurthy and Weymuller (2018) and the Berger and Bouwman (2009) (BB) Measure for our sample of banks.

For a more consistent comparison with the LPI, we apply the LMI to our sample of banks from the subsidiary-level balance sheets in the FF031 filings, whereas the original LMI is applied to conglomerate bank balance sheets from the FF041 filings. We focus on the average bank-level LMI rather than the sector-level aggregate LMI. For the BB measure, we focus on the cat_nonfat measure that do not include off-balance sheets items because our LPI is also estimated without off-balance sheet items.

Because both the LMI and the BB measure capture liquidity provision at the bank-level rather than on a percentage basis, we multiply the LPI by bank asset size and then plot the bank-level average along with the LMI in Panel (a) of Figure A1 and the BB measure in Panel (c) of Figure A1. In these plots, observe that the LPI scaled by bank assets, the LPI, and the BB measure are all increasing over the sample period. This is to a large extent driven by average bank size increasing over the sample period.

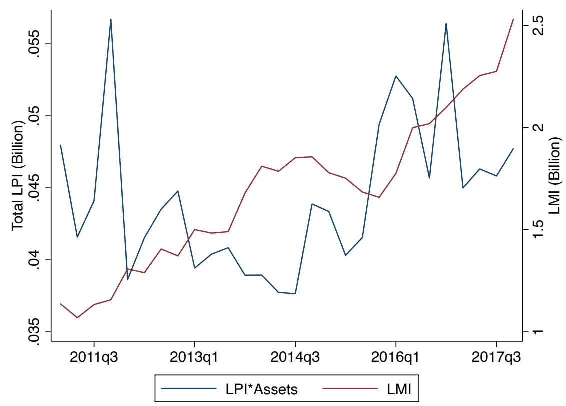
To better understand the liquidity provided per unit of assets, we plot the LMI and BB measure divided by total bank assets and our unadjusted LPI in Panels (b) and (d) of Figure A1. First, notice that the fluctuations in the normalized LMI are negatively correlated with those of the LPI. This difference is driven by changes in asset liquidity that increase liquidity provision, as measured by the LPI, but decreases the available proceeds to pay liability holders in a crisis, as measured by the LMI. For our LPI, an increase in asset illiquidity implies that more liquidity is being provided as long as the default risk is sufficiently low. This is because, without the intermediary, the investor herself would recover a lower value from a portfolio of assets with higher discounts. The contribution of the bank to liquidity provision is thus higher when asset illiquidiy increases. In contrast, the LMI captures the potential shortfall of liquidity if all assets were liquidated on short notice to meet the demand from all liability holders. In this case, an increase in asset illiquidity implies that the proceeds from selling them on short notice decreases, which reduces the LMI.

Second, compared to the LPI and the normalized LMI, the normalized BB measure displays an upward trend with very minimal fluctuations. The absence of fluctuations for the BB measure is because its illiquidity weights, both on the asset and the liability side, are fixed at constant values of -0.5, 0, and 0.5. In contrast, the illiquidity weights for the LPI and the LMI are based on time-varying market-level prices. Regarding the upward trend, one main driver is the treatment of liabilities. While we consider the actual flows observed in the data to estimate the LPI, the BB measure assigns given weights by the type of liability. In particular, time deposits are considered semi-liquid and assigned a weight of 0, whereas savings deposits are considered liquid and assigned a weight of 0.5. The growth of savings deposits over time deposits over this sample period thus made bank liabilities more liquid according to these predefined weights, which contributed to the implied rise in liquidity provision.

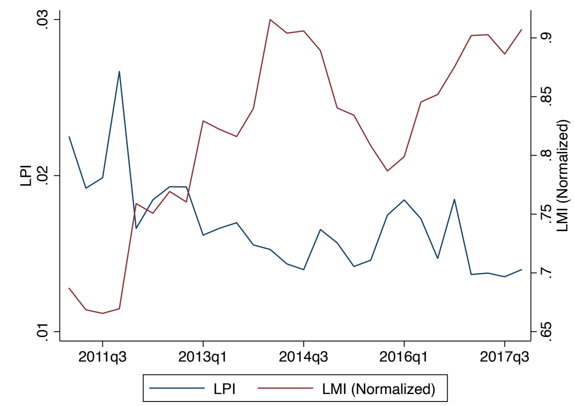
Figure A1: Comparison of Bank Liquidity Provision Measures

Panel (a) plots the average bank-level LPI and the Liquidity Mismatch Index (LMI) by Bai, Krishnamurthy and Weymuller (2018) over time. Panel (b) plots the average bank-level LPI and the Berger and Bouwman (2009) (BB) Measure cat_nonfat over time.

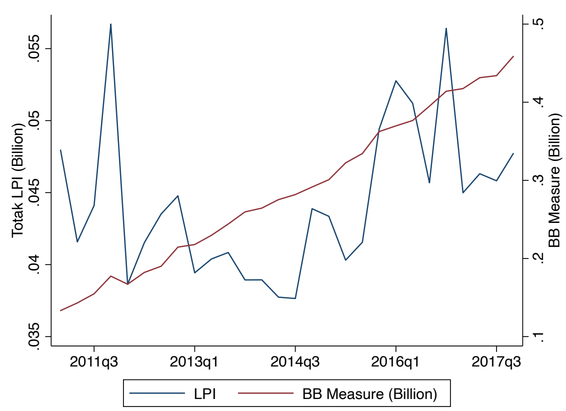
(a) LMI



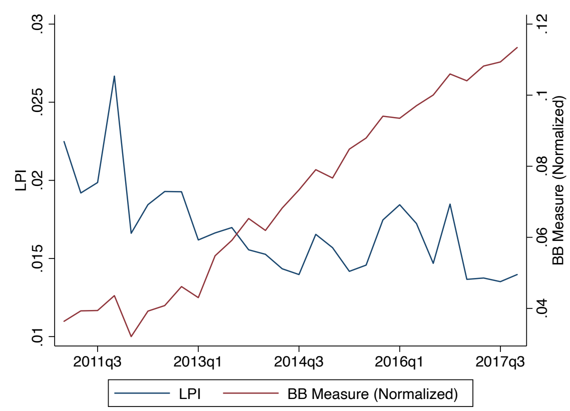
(b) LMI (Normalized)



(c) BB Measure



(d) BB Measure (Normalized)



E Determinants of Realized Fund and Bank LPI

Table A2: Determinants of Realized Fund LPI

This table shows the relationship between realized fund LPI and various fund characteristics, including outflow, cash ratio, 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 adjustments and columns (3) and (4) show the results for fund LPI with partial NAV striking. Explanatory variables are standardized for easier interpretation. LPIs are expressed in bps.

	LPI		LPI (NAV Striking)							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Outflow	-0.01	-0.02	-0.00***	-0.00***	-0.01	-0.02	-0.00***	-0.00***	-0.01	-0.02
	(0.04)	(0.04)	(0.00)	(0.00)	(0.04)	(0.04)	(0.00)	(0.00)	(0.04)	(0.04)
Cash Ratio	-5.78***	-5.78***	-0.00***	-0.00***	-5.78***	-5.78***	-0.00***	-0.00***	-5.78***	-5.78***
	(0.15)	(0.16)	(0.00)	(0.00)	(0.15)	(0.16)	(0.00)	(0.00)	(0.15)	(0.16)
Asset Illiquidity	8.22***	8.23***	0.00***	0.00***	8.22***	8.23***	0.00***	0.00***	8.22***	8.23***
	(0.15)	(0.15)	(0.00)	(0.00)	(0.15)	(0.15)	(0.00)	(0.00)	(0.15)	(0.15)
Expense Ratio	0.42***	0.42***	0.00***	0.00***	0.42***	0.42***	0.00***	0.00***	0.42***	0.42***
	(0.08)	(0.08)	(0.00)	(0.00)	(0.08)	(0.08)	(0.00)	(0.00)	(0.08)	(0.08)
Retail		-0.05		-0.00		-0.05		-0.00		-0.05
		(0.26)		(0.00)		(0.26)		(0.00)		(0.26)
Age		0.18***		0.00***		0.18***		0.00***		0.18***
		(0.07)		(0.00)		(0.07)		(0.00)		(0.07)
Asset Size		-0.04		-0.00		-0.04		-0.00		-0.04
		(0.07)		(0.00)		(0.07)		(0.00)		(0.07)
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
SE Cluster	Fund	Fund	Fund	Fund	Fund	Fund	Fund	Fund	Fund	Fund
Observations	38,081	38,081	38,081	38,081	38,081	38,081	38,081	38,081	38,081	38,081
Adjusted R2	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88

Table A3: Determinants of Realized Bank LPI

This table shows the relationship between realized bank LPI and various bank characteristics, including insured deposit ratio, non-deposit liabilities ratio, default probability, cash ratio, asset illiquidity, and log asset size. Explanatory variables except insured deposit ratio and non-deposit liabilities ratio are standardized for easier interpretation. LPIs are expressed in bps.

	LPI			
	(1)	(2)	(3)	(4)
Insured Dep. Ratio	21.47***	26.82***	27.26***	7.54**
	(5.34)	(4.80)	(5.10)	(3.37)
Non-deposits Liab.		44.71***	-9.04	-9.72
		(13.05)	(12.91)	(8.86)
Asset Illiquidity			36.40***	37.62***
			(1.22)	(0.78)
Default Prob				-17.22***
				(0.26)
Cash Ratio				-32.60***
				(0.29)
Asset Size				1.48***
				(0.39)
Time FE	Yes	Yes	Yes	Yes
SE Cluster	Bank	Bank	Bank	Bank
Observations	182,424	182,424	182,422	182,422
Adjusted R2	0.30	0.30	0.47	0.93

Table A4: Summary Statistics of Liquidation Costs for Mutual Fund Sample

This table shows the summary statistics of the liquidation costs to calculate LPIs. The liquidation costs are expressed in basis points.

	mean	sd	p25	p50	p75
Cash	0.00	0.00	0.00	0.00	0.00
Treasury	1.84	0.43	1.61	1.76	2.08
AgencyDebt	10.81	2.37	9.90	9.90	9.90
AgencyMBS	11.66	2.66	10.44	10.64	10.93
Loan	145.59	177.64	117.34	136.15	165.23
MoneyMarket	19.59	5.22	14.84	21.44	24.74
Muni	26.68	28.34	19.65	24.61	31.83
Corp	30.18	36.82	24.32	28.22	34.25
ABS	40.28	18.88	28.25	35.76	47.89
Equity	4.52	0.46	4.18	4.42	4.80

Table A5: Summary Statistics of Liquidation Costs for Bank Sample

This table shows the summary statistics of the liquidation costs to calculate LPIs. The liquidation costs are expressed in basis points.

	mean	sd	p25	p50	p75
Cash	0.00	0.00	0.00	0.00	0.00
Treasury	1.67	0.07	1.62	1.65	1.72
AgencyDebt	15.11	3.65	13.77	13.77	13.77
AgencyMBS	16.12	3.52	14.64	14.80	15.12
Loan	207.22	49.67	164.54	202.24	231.92
MoneyMarket	28.46	6.80	20.68	30.98	34.42
Muni	36.08	13.13	34.42	34.42	34.42
Corp	42.95	10.29	34.10	41.92	48.07
ABS	56.45	24.56	42.93	49.87	65.18
Equity	4.46	0.44	4.16	4.36	4.79
FixedAsset	688.37	0.00	688.37	688.37	688.37