Mutual Fund Liquidity Transformation
and Reverse Flight to Liquidity*

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Abstract

We document that traditionally liquid asset markets, such as those for Treasuries and high-quality corporate bonds, experienced significant strains from unusually high selling pressures during the Covid-19 pandemic, which contrasts with the conventional wisdom of flight to liquidity during crises. We identify the increased reliance on fixed-income mutual funds for liquidity provision as an important contributing factor to this phenomenon. Theoretically and empirically, we show that fixed-income mutual funds transform liquidity by issuing redeemable fund shares backed by a portfolio of liquid and illiquid assets while meeting redemption requests by first selling more liquid assets in their portfolios. Therefore, when investors redeem their fund shares en masse, funds’ pecking order of liquidation generates pronounced selling pressure for liquid assets, effectively turning investors’ flight to liquidity into the observed reverse flight to liquidity in financial markets. Such volatility in asset markets can be alleviated when financial intermediation is provided by commercial banks.
1 Introduction

The Covid-19 pandemic has led to widespread distress in funding markets. Uncertainty in the pandemic’s trajectory and the speed of economic recovery sparked concerns over companies’ credit quality, which caused a scramble amongst investors to reduce their exposure to illiquid corporate debt. However, the impact was not limited to risky corporate debt. Markets for traditionally liquid and high-quality assets, such as those for Treasuries and high-quality corporate bonds, experienced significant strains from unusually high selling pressures before widespread intervention by the Federal Reserve. This observation is surprising in light of the flight to liquidity phenomenon generally seen in crises, which would suggest buying pressures in high-quality liquid asset markets (e.g., Caballero and Krishnamurthy, 2008, Brunnemeier and Pedersen, 2009).

We find that the increased reliance on mutual funds as financial intermediaries has turned the flight to liquidity by individual investors into an aggregate reverse flight to liquidity in financial markets. Fixed-income mutual funds have continuously grown in size over the past decades. By the end of 2019, they issue around $4.5 trillion of mutual fund shares, which are mostly backed by illiquid assets but can be redeemed at short notice. Mutual funds are able to transform liquidity and provide demandable claims by pooling idiosyncratic liquidity risk across investors similar to Diamond and Dybvig (1983) style banks (Ma, Xiao and Zeng, 2019). In March 2020, however, investors seeking liquidity flocked to redeem their mutual funds for cash en masse, causing an unprecedented 12% aggregate outflow from fixed-income mutual funds within one month. We find that in meeting redemption requests, funds optimally followed a pecking order of liquidation by first selling their most liquid assets before moving on to more-illiquid ones in order to minimize the discounts from asset sales. Pronounced outflows coupled with the pecking order of liquidation lead to the most concentrated sales in the most liquid debt securities by the fixed-income fund sector, contributing to the reverse flight to liquidity phenomenon observed in financial markets.

One may ask to what extent mutual fund liquidity transformation is unique and what the economic significance is. After all, banks also issue demandable deposits and invest in illiquid assets. We argue that the reverse flight to liquidity phenomenon is uniquely attributable to mutual fund liquidity transformation. Unlike banks that issue demandable debt claims, mutual funds issue demandable equity claims, whose redemption value changes in response to fluctuations in the underlying asset value. This equity contract incentivizes investors to consider redeeming shares
at every expected dip in the funds’ portfolio value, rendering the sale of liquid assets in meeting redemptions sensitive to fluctuations in the economy. Banks do not suffer the same sensitivity in their asset liquidations because depositors are promised a fixed interest payment that does not incentivize withdrawal except in bank runs and defaults. Therefore, the increased reliance on intermediation by mutual funds exacerbates strains in traditionally liquid asset markets during downturns.\footnote{Our framework compares the effect of demandable debt funded intermediaries versus demandable equity funded intermediaries on asset markets, where relatively speaking, the value of equity is more adjustable than that of debt. We do not rule out the possibility of first-mover advantage induced runs in practice, where the valuation of fund shares may not be fully flexible and perfectly forward looking.}

Our findings bear important implications for how central bank interventions can alleviate strains in asset markets. Examining the effect of various policies by the Federal Reserve during the Covid-19 crisis, we find that the extended purchase of corporate bonds, including recently downgraded junk bonds, had the largest impact on alleviating outflows from mutual funds compared to other interventions, which confirms the findings by \cite{FalatoGoldsteinHortacsu2020}. We provide a novel explanation through our model—the commitment to purchase more exposed assets like corporate bonds brings about a larger improvement in the benefit from staying with fund compared to the purchase of less exposed securities such as Treasuries. Since less pronounced outflows reduce the sell-off of liquid assets from fund balance sheets, central bank interventions in traditionally less-liquid and more risky asset classes may become an effective tool for alleviating strains in traditionally more liquid asset markets in a world with increased reliance on mutual fund intermediation,

We take several steps to arrive at our results. We first examine the overall asset price movements and the aggregate behavior of fixed-income mutual funds. In March 2020, Treasuries were traded with substantial discounts compared with derivatives that reflect expectations for future US interest rates and sovereign default risks, indicative of increasing selling pressure in Treasury markets. For instance, the CDS-adjusted Treasury-interest swap spread on the 30-year Treasury decreased by around 40 bps. Selling pressures were also present in high-quality corporate bond markets as evident from the divergence between CDS rates and the corporate bond spread for investment-grade bonds reaching and at times exceeding those of high-yield bonds. These events occurred at precisely the same time as an unprecedented outflow from bond mutual funds. In response to the increased redemptions, corporate bond funds in our sample
collectively slashed their Treasury holdings by nearly 4%. This change in portfolio compositions is consistent with the concentrated sale of liquid assets by bond mutual funds.

We develop a model to shed light on the economic mechanisms at play and their implications. The model has Diamond and Dybvig (1983) style investors who face idiosyncratic liquidity shocks. At $t = 0$, they do not know whether they will need to consume early at $t = 1$ or wait until $t = 2$. However, investment decisions have to be made between an illiquid and productive asset and a more liquid asset at $t = 0$. Think of the productive asset as a corporate bond, which has a higher long-run expected return than liquid assets like Treasuries but suffers from steeper discounts when liquidated prematurely at $t = 1$ as in Shleifer and Vishny (1992, 1997). The productive asset is also risky: its expected return is known from the onset, but investors can only infer its realization from an imperfect signal received at $t = 1$. In this environment, investors can pool their resources to jointly invest through a mutual fund, which in return offers redeemable shares with adjustable NAVs. Ma, Xiao and Zeng (2019) show that this intermediation arrangement provides liquidity to early consumers because the fund pools investors’ idiosyncratic liquidity risks and meets redemptions by selling more liquid assets first.

However, liquidity transformation by pooling resources at the fund level comes at the cost of fundamental-driven redemptions by late investors. For late investors, the incentive to stay with the fund until $t = 2$ is to benefit from the long-run return of the project. As the signal of this long-run return deteriorates, the benefit of staying with the fund decreases, and more late investors are inclined to redeem their shares early. Such redemptions are costly for the fund because they require premature liquidations of fund assets. To reduce losses from early liquidations, the fund optimally meets redemption requests by first selling the more liquid Treasuries before tapping into the project that incurs a steeper liquidation discount. Therefore, as negative signals about economic fundamentals emerge and late investors request to redeem their shares, the fund’s pecking order of liquidations leads to more concentrated sales in the more liquid asset. Investors’ flight to liquidity is thereby turned into the mutual fund’s reverse flight to liquidity.

The probability and magnitude of reverse flight to liquidity become more pronounced precisely with increased liquidity transformation. When the fund invests in a productive asset with a higher liquidation discount, it also chooses to hold a larger buffer of the relatively liquid asset. For the fund, this strategy is optimal for minimizing expected losses from premature liquidations.
As a consequence, however, the market for liquid assets is more likely to experience large and concentrated sales when economic fundamentals deteriorate.

In comparison, deposit-issuing banks can provide liquidity without inducing the same volatility in liquid asset markets. While the value of fund shares adjusts flexibly so that investors consider redemptions at every dip in expected long-run returns, bank deposits promise a fixed interest rate so that withdrawal decisions are decoupled from the expected performance of banks’ portfolio except in default. Only when fundamentals in the economy deteriorate past the bank run or default threshold will late depositors run to withdraw their deposits. Once that happens, however, all late investors withdraw to induce a complete liquidation of bank assets. This first-mover advantage in panic runs is eliminated by the flexibly adjusting value of fund shares so that outflows at funds are more continuous with respect to fundamentals. Therefore, the reliance on mutual funds in liquidity provision renders selling pressures in liquid asset markets more sensitive towards general fluctuations in the economy but can better guard against tail events involving outright bank runs.

We proceed to test our model in the data. First, we find that corporate bond funds suffering greater outflows following the Covid-19 shock also experienced a larger decline in their proportion of liquid assets, which includes cash, cash equivalents, and Treasury bills, decreases. For funds with outflows surpassing 4% however, the amount of liquid assets levels off and high-quality corporate bond holdings start to decline. This result implies that as fundamentals deteriorate, more liquid assets are sold before less liquid ones in meeting redemption requests, consistent with the reverse flight to liquidity by mutual funds. Notice that mutual funds’ concentrated sale of traditionally liquid assets like Treasuries and highly-rated corporate debt during the Covid-19 crisis only marks the beginning stages of a more general reverse flight to liquidity phenomenon. If fundamentals deteriorate further (e.g., if the Federal Reserve did not intervene), investors’ redemption requests would expand further and lead to the sale of increasingly illiquid assets from funds’ portfolios. In that case, heightened selling pressure and strains may ensue in markets trading more and more illiquid assets.

Another prediction of our model is that funds investing in more illiquid long-term assets also hold more of a liquid buffer, which raises the probability and potential magnitude of reverse

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2Our model illustrates a benchmark case in which the value of fund equity is fully flexible. The goal is to provide a clear comparison with demandable debt, whose value is fixed. In practice, we can understand the value of demandable equity to be relatively more adjustable than that of demandable debt.
flight to liquidity episodes. Indeed, we find that the average proportion of liquid assets at loan funds, high-yield corporate bond funds, and investment-grade corporate bond funds are at 5%, 3.8%, and 2.5%, respectively. This trend supports the theory because bank loans bear the highest discount when liquidated at short notice in secondary markets, whereas investment-grade corporate bonds incur the least discount. One important implication of this result is that as the mutual fund sector transforms increasingly illiquid assets like lower quality corporate bonds and bank loans into demandable fund shares, concentrated and systematic sell-offs in traditionally liquid asset markets may inevitably increase in frequency and magnitude as well.

Nevertheless, our theory shows that heightened investor redemptions and sell-offs in liquid asset markets are less likely to occur if liquidity transformation was provided by banks instead of funds. To test this conjecture empirically, we create a matched sample of commercial banks and loan mutual funds that resemble each other in their pre-Covid-19 portfolio composition. Using a difference-in-difference approach, we find that outflows at loan funds increased by 6.9% more than that at their matched commercial banks in 2020Q1. Our results are robust to limiting withdrawals to uninsured deposits only, suggesting that the difference in redemptions at banks versus funds cannot be explained by deposit insurance alone.

We further examine the effects of redemptions on the portfolio composition of loan funds versus their matched sample of banks. Our model suggests that equity-issuing funds uniquely contribute to reverse flight to liquidity because their redemptions continuously increase with worsening fundamentals so that asset sales are concentrated in liquid assets first. For banks, the fixed interest on deposits ensures relatively stable withdrawals with limited liquidations. Even in the case of a bank run, there will be a complete and hence proportional liquidation of bank assets.

Indeed, we find that following the Covid-19 shock, loan funds reduced their holding of liquid assets by 1.3% to 1.8% more than commercial banks with similar portfolio composition did. At the same time, the proportion of corporate loans in the portfolio of loan funds expanded by 1.4% to 2.0% more than that at the matched sample of commercial banks.

Our results imply that in the long run, as financial intermediation is increasingly performed by non-bank intermediaries like fixed income mutual funds, liquidity transformation will become more cyclical and traditionally liquid asset markets will experience more pronounced volatility over the course of the business cycle. During downturns in particular, when investors are flocking into cash, there can be large and concentrated selling pressures in more liquid assets such as
Treasuries and high-quality corporate debt. In this sense, the relative liquidity of asset will be
time-varying: the most liquid assets during normal times may also become illiquid when investor
redemptions and fund liquidations turn systematic. For banks, liquidity transformation is stable
and premature asset liquidations are limited except in the tail event of bank runs.

Related Literature

Our findings contribute to the understanding of the liquidity events in financial markets
during the Covid-19 crisis. Through analyzing mutual fund liquidity transformation and its
implications on asset markets, we confirm and provide a plausible explanation for the findings
by Haddad, Moreira, and Muir (2020) and Fleming and Ruela (2020) that there were unusual
stresses in various traditionally liquid asset markets during the Covid-19 crisis. We complement
Duffie (2020) and He, Nagel, and Song (2020), who explain Treasury market strains using dealers’
balance sheet constraints; Schrimpf, Shin and Sushko (2020), who emphasize the role of hedge
funds’ unwinding of Treasury positions; Kargar, Lester, Lindsay, Liu, Weill and Zuniga (2020)
and O’Hara and Zhou (2020), who examine liquidity dry-up in corporate bond markets; Pastor
and Vorsatz (2020), who focus on the performance of equity mutual funds; and Chen, Liu, Sarkar
and Song (2020), who study dealer constraints in the agency MBS market. Falato, Goldstein
and Hortacsu (2020) examine and explain the fragility in mutual fund and ETF flows, whereas
we focus on how mutual funds transform liquidity differently than banks do and the implications
on asset markets. We thereby identify a novel explanation for the volatility in asset markets
during the Covid-19 crisis: the increased reliance on liquidity transformation by mutual funds
turned investors’ flight to liquidity into an aggregate reverse flight to liquidity by open-end fixed-
income mutual funds.\textsuperscript{4} The reverse flight to liquidity phenomenon we establish is not limited to
Treasuries but encompasses a pecking order of increasingly illiquid assets. This is confirmed in
the data, where not only Treasuries but also high-quality corporate bonds suffered heightened
selling pressure.

Identifying the characteristics of mutual fund asset sales in liquidity transformation relates our
paper to a growing literature on fund flows and their financial stability implications. Chen, Gold-
stein and Jiang (2010) and Goldstein, Jiang and Ng (2017) find that funds’ flow-to-performance
relationship is more concave (i.e., flows are more sensitive to bad performance) when the funds
in question hold more illiquid assets. Rather than focusing on how mutual funds resemble banks

\textsuperscript{4}This channel arises because mutual funds optimally sell their liquid asset holdings before illiquid ones in
meeting heightened investor redemptions following shocks to economic fundamentals.
in that their flows may exhibit strategic complementarity, we focus on the differences in their liquidity transformation technologies—the use of demandable equity versus demandable debt. In this respect, we identify mutual funds’ pecking order of liquidations in response to redemptions under aggregate shocks and the resulting asset pricing implications, which uniquely arise under liquidity transformation using demandable equity. In this sense, our findings generalize the message in Chernenko and Sunderam (2017) that mutual funds optimally hold cash and cash equivalents to meet shareholder redemptions, and also help reconcile the results in Choi, Hoseinzade, Shin and Tehranian (2019) and Jiang, Li and Wang (2020), who focus on mutual fund portfolio management and find little direct price impact by mutual fund outflows on the underlying fund assets. Indeed, rather than focusing on the price impact on illiquid bonds, we analyze portfolio changes in general and find more significant selling pressure for the more liquid end of the asset spectrum—the reverse flight to liquidity.

More generally, our results speak to the consequences of financial intermediation and liquidity transformation by non-banks. The traditional intermediation literature has mostly focused on deposit-issuing commercial banks in liquidity provision, e.g., Diamond and Dybvig (1983), Diamond and Rajan (2001), Kashyap, Rajan and Stein (2002), and Goldstein and Pauzner (2005). More recent papers have increasingly considered the effect of non-banks in providing financial intermediation services. Hanson, Shleifer, Stein and Vishny (2015) consider debt claims issued by both banks and shadow banks that differ in their access to deposit insurance, whereas Dang, Gorton, Holmström, and Ordoñez (2017) compare banks to financial markets focusing on banks’ ability to keep information on fundamentals secret.5 Ma, Xiao and Zeng (2019) zoom in on the contractual form of intermediary liabilities to analyze liquidity provision by demandable equity and debt in a unified framework. We build on Ma, Xiao and Zeng (2019) and focus on the impact of liquidity transformation by demandable-equity issuing intermediaries (e.g., fixed-income mutual funds) in asset markets. We find that the adjustable NAV of demandable equity uniquely contributes to mutual funds’ reverse flight to liquidity during economic downturns. Liquidity transformation by commercial banks is less prone to straining traditionally liquid asset markets with heightened selling pressure because of the fixed value of demandable deposits.

The remainder of the paper is arranged as followed. Section 2 explores aggregate trends in asset prices and the behavior of mutual funds in the Covid-19 pandemic to provide initial

5Other papers on shadow bank liquidity provision include Gorton and Metrick (2010), Stein (2012), Sunderam (2015), Nagel (2016), Moreira and Savov (2017) and Xiao (2019).
evidence for how mutual fund liquidity transformation has contributed to the recent reverse flight to liquidity phenomenon. Section 3 develops a model to shed light on the detailed economic mechanisms and implications. Predictions of the model are verified empirically in Section 4. Section 5 concludes the paper and discusses policy implications going forward.

2 Aggregate Trends

We begin by examining developments in financial markets and the overall behavior of the fixed-income mutual fund sector in the first half of 2020, focusing on the developments in the first half of March. The beginning of March was when community spread of Covid-19 within the US became evident and significant damage to the real economy was expected from the impending social distancing measures. In the latter half of March, market conditions became jointly influenced by the Federal Reserve’s widespread policy interventions.

In early March, deteriorating corporate fundamentals lead to a surge in both corporate CDS rates and corporate bond yields, albeit to a different extent. The CDS-bond basis, which is the difference between CDS spread and bond spread, plunged drastically from a stable -10 basis points to below -35 basis points as shown in Figure 1. The divergence between CDS spreads and corporate bond spreads indicates that the (net) pressure to sell corporate bonds became so high that markets became too strained to close the arbitrage. Figure 1 further shows that the CDS-bond basis widening was more pronounced for investment-grade than for high-yield corporate bonds for the majority of the time before interventions by the Fed. \(^6\) Selling pressures in high-quality and traditionally more liquid corporate bonds were therefore higher than selling pressures in lower-rated and traditionally more-illiquid corporate bonds, which is surprising because investors wanting to reduce their exposure to the pandemic should be more inclined to sell the riskier high-yield bonds.

Disruptions were even present in US Treasuries, which are widely seen as the global safe and liquid asset. The CDS-adjusted Treasury swap spread, defined as the interest swap rate minus Treasury yield plus US sovereign CDS rate of the same maturity, dropped significantly in the first half of March as depicted in Figure 2. The demand to sell Treasuries was so high

\(^6\)This observation also suggests that the CDS-bond basis widening cannot be driven by an increase in the cost of dealers’ balance sheet space alone, which should generally apply to all trades.
that the volatility in 10-year Treasury Notes, which is an indicator for market strains, increased by 10% within the first half of March. Heightened selling pressures in some of the most liquid asset classes is surprising because there is usually a flight towards safe and liquid assets during downturns.

We argue that it is the increased reliance on fixed-income mutual funds in liquidity transformation that has turned investors’ flight to liquidity into large and concentrated sales in traditionally liquid asset markets during the Covid-19 crisis. The fixed-income mutual fund sector has experienced an explosive growth spurt over the past two decades. The total asset size of all fixed-income mutual funds has increased from less than $1 trillion in 2000 to more than $4.5 trillion by the end of 2019 (see Figure 3). They have become one of the most important intermediaries investing in corporate bonds, holding more than 20% of all outstanding corporate bonds in 2019. In other words, the mutual fund sector was a significantly more significant player in the US financial system at the onset of the Covid-19 recession than in any previous crisis episode.

At the time when heightened selling pressures emerged in Treasury and high-quality corporate bond markets, the fixed-income mutual fund sector suffered unprecedented outflows. In March 2020, it lost an unprecedented 12% of assets under management, as shown in Figure 4. We further find from Figure 5 that before intervention by the Federal Reserve, cumulative outflows increase in magnitude from Government bond funds to corporate bond funds to loan funds. Within corporate bond funds, outflows at high-yield funds exceeded those at investment-grade funds. This trend is consistent with investors wanting to cut their exposure to the pandemic, and thus redeemed more shares at funds with portfolios more impacted by the worsening real economy.

However, if mutual funds proportionately liquidated their assets to meet redemptions, larger outflows at funds holding lower-quality and more-illiquid assets would have been at odds with selling pressures concentrated in Treasuries and other high-quality liquid assets. Indeed, we find that funds disproportionally sold the most liquid components of their portfolio to pay redeeming investors. For example, corporate bond funds liquidated nearly $30 billion in Treasuries but only $4 billion in corporate bonds (see Figure 6).

The overall share of Treasury securities in corporate bond mutual funds’ portfolio has declined from 14% to 10% in March 2020, whereas the share of corporate bonds and loans has increased from 65% to 75%, as Figure 7 shows. In aggregate, the volume of Treasuries sold by open-end
mutual funds is far from trivial at $80 billion in the first quarter of 2020 (see Figure 8). Compared with the behavior of other financial institutions in the Flow of Funds, the large sale of liquid assets appears unique to the mutual fund sector. In particular, other financial intermediaries like commercial banks did not engage in a net sale of Treasury securities during the same period (see Figure 8).

The aggregate trends in this section provide preliminary evidence that the large amount of redemption by investors coupled with the funds’ use of liquid assets to meet redemption requests ultimately led to a systematic sell-off of liquid assets by the mutual fund sector. This phenomenon was unique to the mutual fund sector and was likely an important contributor to the heightened selling pressures observed in traditionally liquid asset markets in which fixed-income mutual funds have become a significant player in.

3 Model

Following Ma, Xiao and Zeng (2019), we build a model in the spirit of Diamond and Dybvig (1983) with a focus on mutual fund liquidity transformation. The model features aggregate risks (as in Allen and Gale (1998) and Goldstein and Pauzner (2005), for example), which are critical in uncovering the asset market implications of mutual fund liquidity transformation in response to changes in economic fundamentals.

3.1 Setting

The economy has three dates, \( t = 0, 1, 2 \), with no time discount. There is a \([0, 1]\) continuum of ex-ante identical households, each of which has one unit of consumption good at \( t = 0 \), which is the numeraire, and no endowment afterward. Each household is uncertain about her preferences over consumption at \( t = 1 \) and \( t = 2 \). At the beginning of \( t = 1 \), a household learns her preferences privately: with probability \( \pi \) 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. Let the primitive flow utility function, \( u(c) \), be increasing, concave, and satisfy the Inada conditions.
The market is incomplete in the sense that no Arrow-Debreu securities are available. There are three assets: 1) a long-term, relatively more-illiquid asset called “project”, denoted by \( y \), 2) a long-term, relatively more liquid asset called “Treasury”, denoted by \( x \), both being only available at \( t = 0 \), and 3) a short-term asset denoted as “storage”, which is only available at \( t = 1 \).

The project is risky. One unit investment in the project at \( t = 0 \) yields \( R \) units of good at \( t = 2 \), where \( R \) is a random variable that follows a distribution of \( G(\cdot) \) with support \([0, +\infty)\). Denote \( R \) as the fundamentals of the economy; since \( R \) is uncertain, the economy entails aggregate risks. In contrast, the Treasury is riskless; one unit investment in the Treasury at \( t = 0 \) yields 1 unit of good at \( t = 2 \) as a normalization. We assume that \( E[R] > 1 \) so that the project generates a higher expected return than the Treasury.

At \( t = 1 \), both assets have not yet come to fruition and retain a unit value of 1. However, if they are prematurely liquidated at this point, both the project and the Treasury are illiquid and incur a liquidation discount, resulting in a lower marginal liquidation value in the spirit of Shleifer and Vishny (1992, 1997). The project is more illiquid and suffers higher liquidation discounts than the Treasury. We capture the relative difference of illiquidity by modeling two downward-sloping demand curves. The Treasury’s marginal liquidation value is given by

\[
p_x(l_x) = 1 - \phi_x l_x,
\]

where \( l_x \) is the liquidation amount and the price impact parameter \( 0 < \phi_x \leq 1 \) captures the extent of the Treasury’s illiquidity. The project, which is more illiquid, has a marginal value of

\[
p_y(l_y) = \begin{cases} 
1 & \text{if } l_y = 0, \\
\alpha(1 - \phi_y l_y) & \text{if } l_y > 0,
\end{cases}
\]

where \( l_x \) is the liquidation amount and the two parameters \( 0 < \alpha \leq 1 \) and \( 0 < \phi_y \leq 1 \) capture the extent of project illiquidity. Particularly, the parameter \( \alpha \) captures a fixed cost component of project illiquidity in the sense that even liquidating the first unit generates a large discount, consistent with the fixed cost of liquidating illiquid assets such as high-yield bonds and bank loans in reality.
The storage, which is only available at \( t = 1 \) to late households, is riskless but inefficient in that a unit investment only yields \( \gamma \) units of goods from \( t = 1 \) to \( t = 2 \). Specifically, we assume

\[
\gamma = 1 - \kappa n ,
\]

(3.3)

where \( 0 \leq \kappa < 1 \) captures the decreasing returns to scale when a late household operates the storage and \( n \) is the population of late households who use this storage.

To keep the model simple and focused, we do not model cash, which would have a zero liquidation cost at \( t = 1 \), as an asset available to households at \( t = 0 \). The mechanism of mutual funds optimally holding the relatively less illiquid Treasury to help with liquidity transformation would not change if we were to include cash with a fixed supply or with a holding cost. Modeling cash, however, would lead to a portfolio choice problem among three assets and thereby significantly complicate the analysis. In reality, cash holdings by mutual funds are costly for various reasons, and consequently mutual funds predominantly hold near-cash assets such as Treasuries that entail small liquidation costs to help with their liquidity management. In this sense, our model can be viewed as a benchmark in which purely liquid assets such as cash are scarce.

At the beginning of \( t = 1 \), every household \( i \) receives a private signal of \( R \):

\[
s_i = \theta(R) + \varepsilon_i ,
\]

where \( \theta(R) \in [0, 1) \) is strictly increasing in \( R \), and \( \varepsilon_i \) is i.i.d. and arbitrarily small.

In the economy, a representative open-end mutual fund makes portfolio choices \((x, y)\) at \( t = 0 \) on households’ behalf, where \( x \) is the amount of Treasury and \( y \) the amount of projects. Since the mutual fund is representative, it maximizes households’ utility and breaks even in equilibrium. The representative open-end mutual fund also offers an NAV-based equity contract \((c_1(\lambda(R)), c_2(\lambda(R)))\) in which the cash payments are the end-of-date net asset values (NAVs). As a benchmark case, we consider fully adjustable NAV with the contract payment varying with the number of shareholders who redeem at \( t = 1 \), denoted by \( \lambda \). In practice, open-end mutual funds achieve this by “striking the NAV” — a standard industry practice during the trading day to form the estimated amount of redemption requests, perform the necessary asset transactions, and pre-calculate the end-of-day NAVs. We essentially take this process to be frictionless in the model. In equilibrium, withdrawals \( \lambda \) will in turn be determined by fundamentals \( R \), which
is why contract payments depend on $R$ and take the form of $(c_1(\lambda(R)), c_2(\lambda(R)))$.\footnote{Notice that this is an equilibrium outcome and not because contract payments are directly written on households’ private signal $s_i$.} We will henceforth denote the underlying economy as a mutual fund economy.

Before solving the model and analyzing its asset market implications, we first define the notion of reverse flight to liquidity.

**Definition 1.** Reverse flight to liquidity occurs in an economy if there exists a non-zero-measure region $\mathcal{R}$ such that when $R \in \mathcal{R}$, the realized liquidation amount $l_x(R)$ decreases in $R$ and $l_x(R) > l_y(R)$, while the realized liquidation price $p_x(R)$ increases in $R$ and $p_x(R) < p_y(R)$.

Intuitively, reverse flight to liquidity occurs when upon the arrival of bad news about future fundamentals, the Treasury is sold off more than the less liquid project, causing the realized liquidation value of the more liquid asset (i.e., the Treasury) to be lower than that of the less liquid asset (i.e., the project). This is in contrast to the typical flight to liquidity scenario in which there is a net pressure to buy more liquid assets in response to signs of deteriorating fundamentals, and in which the rush into more liquid assets induces their value to rise relative to less liquid assets.

It is important to note the separate but highly related roles of idiosyncratic and aggregate risks in the economy. Mutual fund liquidity transformation provides value to households because it helps households to insure against idiosyncratic liquidity risks which resembles the role of banks in Diamond and Dybvig (1983), a point made in Ma, Xiao and Zeng (2019). In this sense, the presence of idiosyncratic risks in the mutual fund economy justifies why mutual fund liquidity transformation exists in the first place. The presence of aggregate risks then allows us to explore the asset pricing consequences of mutual fund liquidity transformation in response to changes in economic fundamentals.

We also note that Definition 1 does not rely on any specific institutional or contractual settings. In other words, reverse flight to liquidity as in Definition 1 may arise in environments other than our mutual fund economy. This is in line with our paper’s goal to identify mutual fund liquidity transformation as an important contributor to the general reverse flight to liquidity phenomenon. Nevertheless, as we will show, among liquidity-providing financial intermediaries, only those issuing demandable equity, such as open-end mutual funds, uniquely induce reverse
flight to liquidity. Liquidity transformation by deposit-funded commercial banks does not exhibit the same effect.

3.2 Equilibrium Analysis

We work backwards on the mutual fund’s optimal portfolio choice at $t = 0$ and liquidation decision at $t = 1$, taking household decisions into account. First, at $t = 1$, the fund pays out the end-of-day $NAV_1$ to redeeming households. Since the fund does not have any consumption goods on hand, it has to liquidate either or both of the two long-term assets. To highlight the economic essence and avoid unnecessary complexities, we impose a parametric restriction on the level of the project’s price impact:

Assumption 1. $0 < \alpha \leq 1 - \phi_x$.

Assumption 1 means that the project is always more illiquid than the Treasury. In general, the representative fund, which maximizes expected shareholder utility, will first liquidate more liquid assets to avoid premature liquidation of more-illiquid assets. Assumption 1 only requires that the last unit of Treasury liquidated incurs a lower liquidation discount than the first liquidated unit of the project, which ensures that funds first exhaust the Treasury to meet redemptions. Only when the Treasury is depleted will the fund resort to liquidating the project prematurely, which incurs a higher liquidation discount. This implies a pecking order of asset liquidations. As long as the fund optimally holds both types of long-term assets, it will always liquidate the less illiquid Treasury first, followed by the more-illiquid project. Note that relaxing Assumption 1 does not affect our economic intuition; a region of reserve flight to liquidity may exist as long as $\alpha < 1$.

Hence, at $t = 1$, the fund’s end-of-day NAV is determined by

$$NAV_1(\lambda) = \begin{cases} 
    x - \frac{\phi_x}{2} l_x^2 + y & \text{if } l_x > 0 \text{ and } l_y = 0, \\
    x - \frac{\phi_x}{2} x^2 + y - (1 - \alpha) l_y - \frac{\alpha \phi_y}{2} l_y^2 & \text{if } l_x = x \text{ and } l_y > 0.
\end{cases}$$

(3.4)
where both \( l_x \) and \( l_y \) are functions of \( \lambda \) in equilibrium. Indeed, the fund needs to liquidate to a point such that the raised consumption goods are just enough to meet \( \lambda \) redemptions. Hence:

\[
\lambda \text{NAV}_1(\lambda) = \begin{cases} 
    l_x - \frac{\phi_x l_x^2}{2} & \text{if } l_x > 0 \text{ and } l_y = 0, \\
    x - \frac{\phi_x x^2}{2} + \alpha \left( l_y - \frac{\phi_y l_y^2}{2} \right) & \text{if } l_x = x \text{ and } l_y > 0,
\end{cases}
\]  

(3.5)

where the LHS is the total amount of consumption good distributed to redeeming households at \( t = 1 \) and the RHS is the amount of raised consumption goods, both evaluated at the end of \( t = 1 \).

Two important remarks are in order. First, although households’ private signal \( s_i \) at \( t = 1 \) is not contractible and cannot be explicitly written into the NAV, fundamentals \( R \) influence equilibrium payments through affecting the number of households who choose to redeem at \( t = 1 \). Thus, the equilibrium equity contract payment is written in the form of \((c_1(\lambda(R)), c_2(\lambda(R)))\). Second, the value of Treasuries and projects that are not liquidated at \( t = 1 \) remains at 1 because they have not yet come to fruition. This valuation is reflected in the flexibly adjusting NAVs.

Having analyzed the NAV at \( t = 1 \), the fund NAV at \( t = 2 \) is determined by

\[
\text{NAV}_2(\lambda) = \begin{cases} 
    \frac{1}{1-\lambda} (x - l_x + yR) & \text{if } l_x > 0 \text{ and } l_y = 0, \\
    \frac{1}{1-\lambda} (y - l_y) R & \text{if } l_x = x \text{ and } l_y > 0.
\end{cases}
\]  

(3.6)

Taken together, the NAV rules (3.4), (3.5), and (3.6) imply that the fundamental \( R \) uniquely determines the comparison between \( \text{NAV}_1 \) and \( \text{NAV}_2 \) given their flexible adjustments:

**Proposition 1.**

\[
\begin{cases} 
    \text{NAV}_1(\lambda) > \text{NAV}_2(\lambda) & \text{if } R < 1, \\
    \text{NAV}_1(\lambda) = \text{NAV}_2(\lambda) & \text{if } R = 1, \\
    \text{NAV}_1(\lambda) < \text{NAV}_2(\lambda) & \text{if } R > 1.
\end{cases}
\]

Proposition 1 is a generalization of Proposition 4 in Ma, Xiao and Zeng (2019) to a setting with two long-term illiquid assets with varying degrees of illiquidity. Because a late household compares \( \text{NAV}_1 \) and \( \text{NAV}_2 \) (given their private signal about \( R \)) to decide their redemption decision, Proposition 1 implies that the redemption decision is directly linked to and completely determined by fundamentals \( R \).
Proposition 1 is important because it allows us to immediately work out late households’ equilibrium redemption decisions as well as the fund’s liquidation responses. Suppose that after observing $s_i$, $w$ late households choose to redeem at $t = 1$, the total portion of redeeming households is thus
\begin{equation}
\lambda = \pi + w
\end{equation}
since early households always redeem. Given (3.4) and (3.6), the amount of late householders $w$ who choose to redeem at $t = 1$ will be
\begin{equation}
w = \begin{cases} 
0 & \text{if } u(c_1(\lambda)) < E[u(c_2(\lambda)|s_i], \\
(0,1-\pi) & \text{if } u(c_1(\lambda)(1-\kappa w)) = E[u(c_2(\lambda)|s_i], \\
1-\pi & \text{if } u(c_1(\lambda)(1-\kappa w)) > E[u(c_2(\lambda)|s_i].
\end{cases}
\end{equation}
Solving (3.8) under the results of Proposition 1 yields the following important result about fund flow-to-fundamentals relationship and the resulting reverse flight to liquidity according to Definition 1:

**Proposition 2 (Flow-to-Fundamentals and Reverse Flight-to-Liquidity).** Given any date-0 fund position $(x,y)$, let
\begin{align*}
\bar{\pi} &= \frac{x - \frac{\phi_x}{2} x^2}{x - \frac{\phi_x}{2} x^2 + y}, \\
\hat{\bar{R}} &= 1 - \kappa (\bar{\pi} - \pi) +.
\end{align*}

i). When $\pi < \bar{\pi}$, late households optimally withdraw
\begin{equation}
w^*(R) = \begin{cases} 
0 & \text{if } R \geq 1, \\
\bar{\tilde{w}}(R) & \text{if } \hat{\bar{R}} < R < 1, \\
\frac{1-R}{\kappa} & \text{if } R < \hat{\bar{R}},
\end{cases}
\end{equation}
subject to $w^* \leq 1-\pi$ and where $\bar{\tilde{w}}(R)$ is decreasing in $R$. The fund optimally liquidates the Treasury when $\hat{\bar{R}} < R < 1$ and then liquidate the project only when $R < \hat{\bar{R}}$. 

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ii). The flow-induced marginal liquidation value of Treasury is given by:

\[
p^*_x = \begin{cases} 
\tilde{p}_x(R) & \text{if } \hat{R} < R < 1, \\
1 - \phi_x x & \text{if } R < \hat{R},
\end{cases}
\]  

(3.10)

where \(\tilde{p}_x(R)\) is increasing in \(R\) and \(1 - \phi_x x < \tilde{p}_x(R) < 1\).

iii). The flow-induced marginal liquidation value of the project is given by:

\[
p^*_y = \begin{cases} 
1 & \text{if } \hat{R} < R < 1, \\
\tilde{p}_y(R) & \text{if } R < \hat{R},
\end{cases}
\]  

(3.11)

where \(\tilde{p}_y(R)\) is increasing in \(R\) and \(1 - \phi_y y \leq \tilde{p}_y(R) < 1 - \phi_x\).

We graphically illustrate Proposition 2 in Figure 9. For simplicity, there we consider the limiting case of \(\pi \to 0\) with a positive Treasury holding \(x > 0\).

Intuitively, redemption requests by late households at \(t = 1\) continuously increase as their prospect about future economic fundamentals worsen. Because funds follow the pecking order of liquidation in meeting redemptions, the more liquid Treasury is sold off before the less liquid project when fundamentals begin to deteriorate, resulting in reverse flight to liquidity.

Specifically, after ruling out the uninteresting case in which early households’ (exogenous) redemptions require the fund to exhaust all its Treasury holdings (i.e., let the proportion of early households be smaller than \(\pi\)), equation (3.9) shows a negative relationship between late household redemptions \(w\) and fundamentals \(R\) as fundamentals fall below the benchmark value of 1.

To meet investors’ redemption requests, the fund liquidates assets from its portfolio and thereby depresses the marginal liquidation value of the asset being sold. \(\hat{R}\) denotes the cutoff at which fundamentals-induced outflows by late households require the fund to exhaust its Treasury holdings. As shown by equations (3.10) and (3.11), when the shock to fundamentals realizes above the cutoff \(\hat{R}\), the fund only liquidates the Treasury and generating price pressure on the Treasury only. When fundamentals are expected to deteriorate past the cutoff \(\hat{R}\), the fund starts to

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8We verify below that the mutual fund may optimally hold \(x > 0\) even when \(\pi = 0\).

9This is also consistent with empirical evidence that the population of investors subject to purely idiosyncratic shocks is generally small at any given time (e.g., Artavanis, Paravisini, Robles-Garcia, Seru and Tsoutsoura, 2019).
liquidate its project because Treasury holdings have been depleted. As news about fundamentals worsens over the region \((\hat{R}, 1)\), selling pressure for the more liquid Treasury exceeds that for the more-illiquid project. In other words, the realized liquidation value of the Treasury decreases as fundamentals worsen and are lower than the realized liquidation value of the project. According to Definition 1, reverse flight to liquidity occurs over the region \(\mathcal{R} = (\hat{R}, 1)\).

Notice that the above results are intricately tied to mutual funds’ use of demandable equity in liquidity transformation. The flexibility of the NAV allows fund investors’ payoff and redemption decisions to continuously adjust to changes in expected future fundamentals. In meeting the continuously increasing outflows, the sale of the more liquid Treasury is concentrated and occurs before any liquidations of the project with respect to the decline in fundamentals. As we will show, reverse flight to liquidity uniquely arises in equity-funded intermediaries but not in debt-funded intermediaries like commercial banks.

Taking the above analysis into account, the representative fund solves the optimal portfolio allocation \((x, y)\) at \(t = 0\) to maximize the expected utility of all households:

\[
\max_{x, y} E \left[ \lambda u(c_1(\lambda)) + (1 - \lambda)u(c_2(\lambda)) \right]
\]

subject to (3.4), (3.6), (3.7), and (3.8).

One important question concerning the fund’s optimal portfolio choice is whether to invest in more or less Treasury at \(t = 0\) when \(\alpha\) or \(\phi_y\) increases. This question is of important empirical relevance because, as equation (3.10) in Proposition 2 makes clear, when reverse flight to liquidity happens, the lowest possible liquidation value of the Treasury is

\[
p_x = 1 - \phi_x x,
\]

which is decreasing in \(x\). In words, a fund that holds more Treasury can potentially generate a higher price pressure on Treasury. The following proposition shows that, when the fund transforms more liquidity in the sense that its underlying project is more illiquid, it will optimally hold more Treasury, but may induce more severe reverse flight to liquidity.

**Proposition 3** (Asset illiquidity and reverse flight-to-liquidity). Consider an economy in which reserve flight to liquidity happens according to Definition 1. When \(\alpha\) decreases or \(\phi_y\) increases, the fund’s optimal Treasury holding \(x^*\) increases, the lowest possible Treasury liqui-
Proposition 3 is established by applying the Implicit Function Theorem to the first order condition of the fund’s optimization problem (3.12), provided that reserve flight to liquidity occurs in the economy. This proposition has two important implications. In the cross-section, Proposition 3 suggests that funds investing in more-illiquid productive assets (i.e., transforms more liquidity) optimally hold a larger amount of liquid assets as well. This is consistent with observations during the Covid-19 pandemic, in which more-illiquid mutual funds experienced more severe outflows, and in turn, liquidated a larger amount of liquid assets like Treasuries. In the aggregate time series, a mutual fund sector that transforms more liquidity is also likely to generate more severe reverse flights to liquidity. Since the mutual fund sector has been investing in more and more illiquid assets in reality, Proposition 3 suggests that reverse flight to liquidity is more likely to occur today than in the past, and may become increasingly prominent in the future.

3.3 A Bank Benchmark

To demonstrate how mutual fund liquidity transformation uniquely contributes to reverse flight to liquidity, we provide a benchmark economy in which a comparable bank transforms liquidity by investing in illiquid assets and issuing demandable debt. We show that reverse flight to liquidity, defined by Definition 1, does not occur in this bank economy.

The main difference between the bank benchmark and the mutual fund economy lies in the contract form of the intermediary. Rather than offering an NAV-based equity contract, the bank offers a demandable debt contract \((c_1, c_2)\) that is subject to a sequential service constraint at \(t = 1\). At \(t = 0\), the bank also chooses the optimal portfolio \((x, y)\) to maximize ex-ante expected household utility.\(^{10}\)

We use the global games technique following Goldstein and Pauzner (2005) to pin down the probability of panic runs and link it to fundamental news. We assume \(\theta\) to be uniformly distributed, and that \(\varepsilon_i\), the i.i.d. noise term, is uniformly distributed over \([-\varepsilon, \varepsilon]\), where \(\varepsilon\)

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\(^{10}\)Thus, this bank benchmark essentially constructs an extension to the bank economy in Ma et al. (2019) with two illiquid assets, which inherit the possibility of panic runs at \(t = 1\).
is arbitrarily small. We follow the same argument in Ma, Xiao and Zeng (2019) to show the existence of a threshold $R^*$ below which bank runs uniquely occur. Thanks to the structure of this threshold equilibrium, we can then show that reverse flight to liquidity does not occur in this benchmark economy with bank liquidity transformation.

**Proposition 4.** Given any date-0 bank position $(x, y)$, the promised debt value $c_1$, and the signal $s_i$ received by households at $t = 1$, there exists a unique run threshold $R^* > 0$. There does not exist any non-zero-measure set $\mathcal{R}$ in which $p_x^*(R) < p_y^*(R)$ or $l_x^*(R) > l_y^*(R)$, that is, reverse flight to liquidity never happens according to Definition 1.

We graphically illustrate Proposition 4 in Figure 10 under the limiting case of $\pi \to 0$ for simplicity (note that Proposition 4 holds for any general $\pi$).

The proof of Proposition 4 is similar to that of Proposition 1 in Ma, Xiao and Zeng (2019), with the additional step of showing that reverse flight to liquidity never occurs. The economic intuition follows from the nature of banks using demandable debt to transform liquidity. Unless panic runs occur, late households’ withdrawals never directly respond to news about future fundamentals because debt promises a fixed value. Early households’ withdrawals, if any, are independent of news about future fundamentals as well. Therefore, in the absence of runs, deteriorating fundamental news does not induce changes in withdrawal requests nor liquidations of either Treasury or the project. When panic runs occur, investors withdraw from the bank altogether, leading to a complete and thus proportional liquidation of all bank assets. In either case, the realized liquidation value of the Treasury never drops below that of the project, and there does not exist a region in which the liquidation value of the Treasury continuously declines with worsening prospects about future fundamentals.

We note that the “all-or-nothing” pattern of asset liquidation by banks in Proposition 4 serves as a benchmark. The general message is that the fixed value promised by bank deposits induce discontinuous withdrawals with respect to changes in fundamentals, in contrast to the continuously increasing redemptions with worsening fundamentals in the case of fund equity. Discontinuous withdrawals render the sequential liquidation of increasingly illiquid assets less relevant: before fundamentals reach the run threshold, withdrawals and liquidations are minimal; after the run-threshold is crossed, withdrawals feed off each other and tend to induce more complete (and thus proportional) asset sales.
Jointly interpreting Propositions 2 and 4 offers a plausible explanation for why there was pronounced reverse to liquidity during the Covid-19 crisis but not during the 2008-2009 financial crisis. It is the increased importance of equity-issuing bond mutual funds relative to deposit-funded banks (see Figure 3), which has rendered investors’ redemptions and intermediaries’ asset sales more sensitive to fluctuations in economic fundamentals. In particular, mutual funds’ pecking order of liquidation induces concentrated and systematic sales of more liquid assets, posing potential strains to traditionally liquid asset markets during economic downturns.

4 Empirical Analysis

In this section, we proceed to test the main results of our model. We begin by demonstrating reverse flight to liquidity by bond mutual funds during the Covid-19 crisis. Then, we examine how fund portfolio composition varies with asset liquidity. Then, we construct a matched sample of loan funds and commercial banks to compare and contrast the characteristics of liquidity transformation by demandable equity and debt issuing financial intermediaries. Finally, we explain the effect of Federal Reserve interventions through the lens of our model.

4.1 Data

Our analysis relies on US fixed-income mutual fund data from the Center for Research in Security Prices (CRSP) and Morningstar as well as US commercial bank data obtained from Call Reports.

**Mutual fund data.** Our main sample includes all open-end US fixed-income mutual funds. The sample period is from 2019Q1 to 2020Q1. For each fund, we observe its securities holdings, portfolio returns, and assets under management by quarter. We also obtain the daily fund flows for a subsample of funds from Morningstar for the sample period from January 1, 2020 to April 30, 2020. Table 1 presents the summary statistics of the mutual fund sample as of January 2020.

**Commercial bank data.** Our second sample includes a subset of US commercial banks from 2019Q1 to 2020Q1. For each bank, we observe quarterly portfolio composition by asset class and deposit flows. To compare loan funds against commercial banks, we select a subset of commercial banks similar to loan funds in terms of their asset holdings to form a matched sample. Specifically, for each loan fund, we choose a bank with similar cash, government bonds,
and loan holdings as of 2019Q1. Table 2 presents summary statistics for the bank-fund matched sample.

### 4.2 Reverse Flight to Liquidity

As shown in Figure 4 of Section 2, fixed-income mutual funds faced significant outflows during the Covid-19 pandemic. The increase in investor redemptions is consistent with model predictions, whereby a reduction in future expected cash flows to firms negatives affects expected returns on corporate bonds and loans held in funds’ portfolio.

Proposition 2 further shows that the optimal strategy in meeting redemption requests is to sell more-liquid assets before more-illiquid ones to reduce the liquidation discounts incurred. We test this prediction in the data by relating the changes in portfolio composition to the magnitude of investor outflows. Figure 11 depicts the kernel-weighted relationship between changes in holdings of liquid assets and AAA-rated debt securities and fund outflows for US corporate bond funds in March 2020. We observe that the proportion of liquid assets, which comprise cash, cash equivalents, and Treasuries, decreases with increasing fund outflows. For funds with outflows reaching beyond 4%, the proportion of liquid assets levels off, but the proportion of AAA-rated debt securities begins to decrease. These trends confirm that funds use liquid assets to meet redemptions first before tapping into the relatively less liquid AAA-rated debt securities. In other words, more liquid assets experienced larger sell-offs and realized liquidation discounts due to the Covid-19 shock, consistent with the reverse flight to liquidity region in Proposition 2.

Notice that in practice, reverse flight to liquidity does not only speak to holdings of cash, Treasuries, and AAA-rated debt securities. Instead, it is a continuous phenomenon whereby as fundamentals deteriorate, relatively more liquid tranches of the portfolio are sold before the sale and of relatively less liquid tranches. By the same token, as fundamentals deteriorate, more liquid tranches of the portfolio experience heightened selling pressure and drops in liquidation value before relatively less liquid tranches. During the Covid-19 pandemic, mutual funds’ concentrated sale of traditionally liquid assets like Treasuries and highly-rated corporate debt only marks the beginning stages of the general reverse flight to liquidity phenomenon. If fundamentals were to deteriorate further (e.g., if the Federal Reserve did not intervene), investors’ redemptions requests would rise and lead to the sale of increasingly illiquid assets from funds’ portfolios. In
that case, heightened selling pressure and strains may ensue in markets trading more and more illiquid debt securities.

4.3 Asset Illiquidity and Reverse Flight to Liquidity

Another prediction of our model is that funds investing in more-illiquid long-term assets also hold more liquid assets as a buffer, which leads to a higher probability of the more liquid asset experiencing heightened liquidations (Proposition 3). In the data, loan funds hold 5% of their portfolio in the form of cash, cash equivalents, and government bonds, whereas the proportion of liquid assets held by high-yield corporate bond funds and investment-grade corporate bond funds is at 3.8% and 2.5% respectively (see Figure 12). This trend supports Proposition 3 because relatively speaking, corporate loans suffer the highest discount when liquidated at short notice in secondary markets, whereas investment-grade corporate bonds incur the least discount.

The observed portfolio choices are optimal in minimizing expected discounts from early liquidation of assets. However, as the mutual fund sector invests in increasingly illiquid assets like lower-quality corporate bonds and loans, their demand for holding liquid assets in normal times increases with the likelihood of systematic sell-offs in traditionally liquid asset markets during downturns. As our theory shows, the potential for heightened volatility in liquid assets is unique to liquidity transformation by mutual funds issuing demandable equity. It would be less likely to occur if illiquid assets like corporate loans were intermediated by demandable-debt funded commercial banks instead. The next subsection presents empirical evidence in this regard.

4.4 Liquidity Transformation by Mutual Funds versus Banks

Comparing the effects of liquidity transformation by mutual funds versus commercial banks is challenging. The ideal environment in which we observe mutual funds intermediating a given set of assets and banks intermediating the same set of assets does not exist. Instead, we create a matched sample of commercial banks and loan mutual funds that resemble each other in their asset composition as a laboratory to compare and contrast the consequences of their liquidity transformation. Specifically, we use the Covid-19 crisis as a shock to fundamentals to show that demandable equity-issuing funds uniquely contribute to the reverse flight to liquidity phenomenon. This is achieved in two steps: (1) funds experienced increased outflows relative to
banks given the same shock to fundamentals; and (2) funds disproportionately sold liquid assets over less liquid assets relative to banks.

We start with open-end loan funds, who invest in corporate loans similar to commercial banks’ loans. Then, we match one commercial bank to each loan fund without replacement using a propensity score. Matching criteria include cash and cash equivalents, government bonds, and loans as a proportion of total assets in 2019Q1. Table 2 shows summary statistics for the matched sample, which comprises of 66 funds and 66 banks. Overall, the match performs well along observable dimensions. The proportion of corporate loans in loan funds averages 81.6%, which is very close to the 81.1% in the matched sample of commercial banks. The proportion of cash and Treasuries held by matched banks is slightly higher than that held by funds, but this may be partially compensated by a higher holding of relatively liquid asset-backed securities by funds.

Next, we examine outflows at loan funds and their matched banks leading up to the Covid-19 crisis. Figure 13 plots the average quarterly redemptions and shows that the level of redemptions in the two samples remains relatively constant throughout 2019, which was a period without major disruptions to the real economy.\textsuperscript{11} This observation is consistent with the theory because even with adjusting NAVs, changes in the incentive to redeem are limited when shocks to expected future fundamentals are small to begin with. For bank deposits promising a fixed value, withdrawal spikes are even less likely during this period as the threat of the bank defaulting and not honoring deposit payments is remote without major expected deterioration in the economy.

In 2020Q1, however, the rate of redemptions at loan funds increasingly diverged from that at their matched banks (Figure 13). From the perspective of the model, the increase in redemptions from around 5% in 2019Q4 to 12% in 2020Q1 at loan funds follows a worsening of expected future fundamentals (due to the impending pandemic, in this case), which lowers the expected long-run NAV of the fund and induces heightened investor redemptions. At banks, however, outflows largely remained at their 2019 levels. The stability of flows at banks arises from their use of demandable debt. Specifically, the worsening of fundamentals has not yet crossed the threshold of panic runs so that investors still expect to obtain the same fixed interest on deposits and are not attracted to more withdrawals. Notice that the absence of increased withdrawals at banks is

\textsuperscript{11}Note that the level of redemptions for the two samples is stable yet different. This could be for a variety of reasons, including a different long-run growth rate of the sector, which is not in our benchmark model. For this reason, we focus on interpreting the deviations in redemptions relative to their overall levels.
the first step for showing that liquidity transformation through banks eliminates reverse flight to liquidity. After all, without heightened withdrawals, there is no need for selling assets (including liquid ones) in the first place.

In reality, the likelihood of bank runs may also be influenced by regulatory features such as deposit insurance. To address this concern and to formally test the difference in redemptions at banks versus loan funds during the Covid-19 crisis, we perform a range of difference-in-difference estimates on outflows. Loan funds constitute the treatment group because our theory predicts increased outflows for demandable equity funded intermediaries following shocks to fundamentals. The matched sample of banks are exposed to the same shocks to fundamentals through their similar asset holdings but should not experience increased withdrawals because they promise a fixed payoff to depositors.\textsuperscript{12} Hence, they are the control group. We take the shock to fundamentals to start in 2020Q1, which, as evident from Figure 13, marks the beginning of increased redemptions. Notice that the stability in redemptions before 2020Q1 points to the unanticipated nature of the Covid-19 crisis. If investors expected future deteriorations in fundamentals earlier, redemption requests would have surged sooner as well.

Columns (1) to (3) in Table 3 state the difference-in-difference estimates for total redemptions of bank deposits and fund shares. We find that following the Covid-19 shock, equity-funded loan funds suffer a 6.9% higher jump in redemptions than demandable-debt funded banks holding similar assets. The statistical and economic significance of our results is unchanged by the inclusion of bank/fund fixed effects and time fixed effects. The results are also robust to limiting the analysis to withdrawals of uninsured deposits only, suggesting that the difference in redemptions at banks versus funds cannot be explained by deposit insurance alone.

We further examine the effects of redemptions on portfolio compositions. Table 4 shows the difference-in-difference estimates for the percentage of liquid assets and corporate loans in funds’ and banks’ portfolio, where liquid assets are the sum of cash, cash equivalents, and Treasuries. As before, loan funds make up the treatment group and 2020Q1 indicates the post period. The results in columns (1) to (3) indicate that following the Covid-19 shock, loan funds reduced their holdings of liquid assets by 1.3% to 1.8% more than commercial banks with similar portfolio composition before the shock. At the same time, the proportion of corporate loans in the portfolio of loan funds expanded by 1.4% to 2.0% more than that at commercial banks with similar

\textsuperscript{12}To be precise, this statement holds if the threshold for bank runs is not yet crossed, which was realistically the case during the first stages of the Covid-19 crisis in March 2020.
portfolio composition before the shock. One concern is that the loan volumes at commercial banks are mechanically driven by firms increasing their use of credit lines following the Covid-19 shock. To this end, we rerun our analysis by considering the sum of loans on balance sheet and unused loan commitments and obtain similar findings as in the baseline (see Table 5). Taken together, these results suggest that demandable-equity-funded loan funds disproportionately sold off liquid assets over illiquid assets in meeting the heightened redemptions requests following the Covid-19 shock. Consistent with model predictions, this behavior was unique because banks that held similar pre-Covid-19 portfolios experienced relatively limited changes in withdrawals and portfolio holdings.

4.5 Effect of Federal Reserve Intervention

Finally, we show that the response in fund flows and NAVs to Federal Reserve interventions is consistent with our model predictions. In response to Covid-19’s disruptions to financial markets and the real economy, the Federal Reserve rolled out a series of policy interventions. Most relevant to our analysis are those concerning the purchase of bonds. On March 15, the intention to buy at least $500 billion in Treasury securities and $200 billion in government-guaranteed mortgage-backed securities over “the coming months” was announced. On March 23, the Fed committed to purchasing corporate bonds for the first time in history through the Primary Market Corporate Credit Facility (PMCCF) and the Secondary Market Corporate Credit Facility (SMCCF). These purchases were limited to investment grade corporate bonds and US exchange traded funds investing in US investment grade corporate bonds. These limits were relaxed on April 9, when the cap on both facilities expanded to $850 billion and the coverage was extended to include high-yield bonds that were investment grade as of March 22.

We first evaluate the impact of the various policy announcements on fund flows. From Table 6, we see that the purchase of corporate bonds on March 23 and especially its expansion on April 9 alleviated outflows to high yield and investment grade corporate funds. This is in contrast to the purchase of Treasuries, which did not have a positive impact on subsequent fund flows. To ensure that the coefficients capture an announcement effect, we control for the trajectory of the pandemic using the growth rate of infections, use fund fixed effects to remove fund-level heterogeneities, and absorb time trends using month fixed effects. Our empirical findings are consistent with our model predictions. The Fed’s commitment to buy a security corresponds to
an improvement in its expected return, where the effect is more pronounced for risky securities exposed to the pandemic such as corporate bonds. Therefore, mutual funds holding corporate bonds experience an improvement in the expected future fundamentals of their risky asset, which renders it more attractive for investors to stay with the fund (i.e., reduces outflows). On the other hand, expected purchases of Treasury securities cannot change investor’s expectation about the realization of future fundamentals of the risky asset, which is a main determinant in their decision to redeem.

The announcement effects on fund NAVs are generally aligned with the results on fund flows. As before, we control for the trajectory of the pandemic using the growth rate of infections, use fund fixed effects to remove fund-level heterogeneities, and absorb time trends using month fixed effects. From Table 7, we find that the extended corporate bond purchase on April 9 lead to the largest and most consistent increase in fund NAVs. This increase could be directly through raising the valuation of corporate bonds held in funds’ portfolios. At the same time, a reduction in outflows reduces the need to liquidate assets at short notice and alleviates the impact of liquidation discounts on fund NAVs. One evidence in support of the latter channel is provided by government funds, which experienced an increase in NAVs following the corporate bond purchase announcements. This may seem surprising at first because government bond funds do not directly hold corporate bonds. If anything, demand may shift away from them towards fund types directly benefiting from the announced purchases. However, this phenomenon can be rationalized by our model. When the announcement of corporate bond purchases curbs outflows at corporate bond funds, their liquidation of relatively liquid assets like Treasuries is reduced, which reduces the price pressure in these liquid asset markets. As a result, the NAV of government bond funds that invest in Treasuries is improved.

Taken together, our results imply that central bank interventions in traditionally less liquid and more risky asset classes such as corporate bonds may become an effective tool for alleviating strains in traditionally more liquid asset markets in a world with increased reliance on mutual fund liquidity transformation. During the Covid-19 crisis, central bank support for risky asset classes such as corporate bonds were more effective at alleviating strains in traditionally liquid asset markets because they prevented fund outflows and liquidations from the onset. In contrast, the purchase of liquid assets like Treasuries after they have been sold off by mutual funds crucially depends on the efficient functioning of intermediaries and dealers of these liquid assets. However,
as Duffie (2020) shows, dealers’ intermediation of Treasuries during the Covid-19 pandemic was strained because of elevated selling pressure and costly balance sheet capacity.

5 Conclusion

In this paper, we theoretically and empirically show that liquidity transformation by bond mutual funds contributes to volatile and concentrated selling pressure in liquid asset markets. Such reverse flight to liquidity by mutual funds arises because the NAV of fund shares continuously adjusts when expected future fundamentals worsen, leading to a continuous increase in investor redemptions. In meeting redemption requests, funds optimally deplete their stock of liquid assets first before tapping into more-illiquid ones to minimize expected liquidation discounts. Consequently, heightened selling pressure may be concentrated in more liquid asset markets, as witnessed during the Covid-19 crisis. On the other hand, the fixed value of deposit contracts at commercial banks renders depositor withdrawals and bank-level asset sales insensitive to changes in economic fundamentals.\textsuperscript{13}

In the long run, if financial intermediation is increasingly performed by non-bank intermediaries like fixed-income mutual funds, liquidity transformation will become more cyclical and traditionally liquid asset markets will experience more pronounced volatility over the business cycle. During downturns in particular, when investors are flocking out of fund shares and into cash, there can be large and concentrated selling pressures in more liquid assets such as Treasuries and high-quality corporate debt. Liquidity transformation performed by commercial banks is more stable, and premature asset liquidations are limited except in the tail event of bank runs.

With the increased reliance on mutual fund liquidity transformation and the potential for future reverse flight to liquidity episodes, central bank interventions in traditionally less liquid and more exposed asset classes such as corporate bonds may become an effective tool for alleviating strains in traditionally more liquid asset markets. Central bank support for more exposed asset classes can alleviate fund outflows and liquidations from the onset, whereas the effectiveness of purchasing liquid asset like Treasuries after they have been sold off by mutual funds varies with the (expected) efficiency of trading in secondary markets. As Duffie (2020) points out, Treasuries

\textsuperscript{13}Even if the default threshold is reached and depositors run on the bank, asset sales tend to be complete and hence proportional rather than concentrated in liquid assets only.
are traded over-the-counter and dealers’ balance sheet constraints coupled with elevated selling pressures may impose significant strains on trading efficiency.
References


Figure 1: CDS-Bond Basis of US Corporate Bond Markets
This graph plots the CDS-bond basis for investment-grade and high-yield US corporate bonds from January 1, 2020 to April 30, 2020. The CDS-bond basis represents the difference between the CDS rate and the bond yield spread. The solid and dashed line indicate CDS-bond basis for investment grade and high yield, respectively. Data source: Bloomberg, FRED.
Figure 2: Treasury CDS-adjusted Swap Spreads and Volatility during Covid-19
The upper panel plots the US Treasury CDS-adjusted adjusted swap spreads, defined as interest swap rate minus Treasury yield plus US sovereign CDS rate with the same maturity. The sample period is January 1, 2020 to April 30, 2020. The lower panel plots the CBOE 10-Year Treasury Note Volatility over the same sample period. Data source: Bloomberg, FRED.
Figure 3: Size of the US Fixed-Income Mutual Fund Sector

This graph plots the total asset size of the US fixed-income mutual funds from 1995 to 2019. Fixed-income funds include government bonds funds, corporate bond funds, loan funds, and multi-sector bond funds. The lower panel plots the share of corporate bonds and Treasuries held by US fixed-income mutual funds over the same sample period. Data source: ICI.
Figure 4: Fund Flows to US Fixed-Income Funds
This graph plots monthly fund flows to US fixed-income mutual funds from 2000 to 2020 as a percentage of fund size. Data source: Morningstar.
Figure 5: Fund Flows and Fund NAVs by Fixed-Income Fund Type
This upper panel plots asset-weighted cumulative fund flows for US fixed-income funds. The lower panel plots their average cumulative returns. The sample period is from January 1, 2020 to April 30, 2020. Data source: Morningstar.
Figure 6: Change in Bond Holdings by US Fixed-Income Funds
The upper panel plots changes in Treasury holdings by corporate bond and government bond funds for January, February and March 2020. The lower panel plots changes in corporate bond holdings by corporate bond and government bond funds over the same periods. Data source: Morningstar.
Figure 7: Portfolio Holdings of US Corporate Bond Funds
This graph plots the average portfolio weights of corporate bond funds. The “others” category includes asset-backed securities, cash, and common and preferred stocks. The sample period is 2019Q1 to 2020Q1. Data source: CRSP.
Figure 8: Changes in Treasury Holdings
This graph plots changes in Treasury securities holdings for different financial intermediaries from 2019Q4 to 2020Q1. Data source: Flow of Funds, Financial Accounts of the United States - Z.1
Figure 9: Reverse Flight to Liquidity

This graph depicts the flow-induced liquidation value for the two long-term assets, “Treasury” and “project”, with respect to future fundamentals at the limit of $\pi \to 0$ and with a positive Treasury holding $x > 0$ in the mutual fund economy. The horizontal axis denotes future fundamentals $R$, and the vertical axis denotes the marginal liquidation value induced by fund outflows. The red and blue lines represent the “Treasury” and the “project”, respectively. Reverse flight to liquidity happens in the fundamental region $(\hat{R}, 1)$. 
Figure 10: No Reverse Flight to Liquidity in Bank Benchmark

This graph depicts $t-1$ flow-induced liquidation value for the two long-term assets, “Treasury” and “project”, with respect to future fundamentals at the limit of $\pi \to 0$ and a positive Treasury holding $x > 0$ in the bank benchmark economy. The horizontal axis denotes future fundamentals $R$, and the vertical axis denotes the marginal liquidation value induced by fund outflows. The red and blue lines represent the “Treasury” and the “project”, respectively.
Figure 11: Relationship between Fund Flows and Changes in Portfolio Holding
This graph plots the relationship between fund flows and changes in portfolio holding for all US corporate bond funds from Feb 2020 to March 2020 using kernel-weighted local polynomial smoothing. Data source: Morningstar.
Figure 12: Liquid Asset Holdings by Fund Type
This graph plots the fund-size weighted average portfolio weight of liquid assets for different types of fixed-income funds in January 2020. Liquid assets include cash, cash equivalents, and government bonds. Data source: Morningstar.
Figure 13: Redemptions at Loan Funds and Banks (Matched Sample)
This graph plots the quarterly redemptions (in percentages) of bank deposits and fund shares for a matched sample of loan funds and commercial banks. The solid dots represent average redemptions and the marked intervals represent the 5th and 95th percentile of redemptions. The sample is matched by constructing a propensity score based on the portfolio weights of cash, government bonds and corporate loans. The sample period is from 2019Q2 to 2020Q1. Data source: Morningstar and Call Reports.
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<th></th>
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<th>Investment grade</th>
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<th>Bank loan</th>
<th>Multi-sector</th>
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<td>1.22</td>
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<td>0.00</td>
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<td>1.12</td>
<td>0.00</td>
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<tr>
<td>AAA</td>
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<td>2.12</td>
<td>1.28</td>
<td>43.76</td>
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<td>1.64</td>
<td>2.61</td>
<td>5.57</td>
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</table>

This table presents the summary statistics of different types of US fixed-income mutual funds. Assets are in billion. The portfolio weights are in percentages of total assets. The sample period is January 2020. Data source: Morningstar.
<table>
<thead>
<tr>
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<th>Fund</th>
<th>Diff</th>
<th>t-stats</th>
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<tr>
<td>Corporate loans</td>
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<td>81.63</td>
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<td>Asset-backed securities</td>
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<tr>
<td>Mortgage-backed securities</td>
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<td>Corporate equity</td>
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<td>-2.89</td>
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</table>

This table reports the average portfolio weights of a matched sample of loan funds and commercial banks. The sample is matched by constructing a propensity score based on the portfolio weights of cash, government bonds and corporate loans. The sample period is 2019Q1. Data source: CRSP, Morningstar, and Call Reports.
<table>
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<td>Total</td>
<td>Total</td>
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<td>Uninsured</td>
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<td>6.835***</td>
<td>6.930**</td>
<td>5.861**</td>
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<tr>
<td>Time F.E.</td>
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<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<td>Observations</td>
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<td>497</td>
<td>497</td>
<td>497</td>
<td>497</td>
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<tr>
<td>Adj. R-squared</td>
<td>0.354</td>
<td>0.198</td>
<td>0.349</td>
<td>0.327</td>
<td>0.274</td>
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</table>

This table presents difference-in-difference estimates of redemptions in a matched sample of loan funds and commercial banks. The sample period is from 2019Q2 to 2020Q1. For loan funds, redemptions are measured as a percentage of total assets. For commercial banks, columns (1) to (3) measure redemptions of total deposits, while columns (4) and (5) measure redemptions of insured and uninsured deposits respectively. *Post* is a dummy variable equal to one in 2020Q1 and *Treat* is a dummy variable equal to one for loan funds. The sample is matched by constructing a propensity score based on the portfolio weights of cash, government bonds and corporate loans. Standard errors in brackets are clustered by quarter. Data source: CRSP, Morningstar, and Call Reports.
<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Liquid</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Liquid</td>
<td>-1.933***</td>
<td>-1.512***</td>
<td>-1.933***</td>
<td>2.472**</td>
<td>1.880**</td>
<td>2.472**</td>
</tr>
<tr>
<td></td>
<td>[0.304]</td>
<td>[0.317]</td>
<td>[0.304]</td>
<td>[0.626]</td>
<td>[0.579]</td>
<td>[0.626]</td>
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<td>Bank/Fund F.E.</td>
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<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Time F.E.</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
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<tr>
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<td>623</td>
<td>623</td>
<td>623</td>
<td>623</td>
<td>623</td>
</tr>
<tr>
<td>Adj. R-squared</td>
<td>0.826</td>
<td>0.032</td>
<td>0.826</td>
<td>0.968</td>
<td>-0.004</td>
<td>0.969</td>
</tr>
</tbody>
</table>

This table presents difference-in-difference estimates of portfolio composition in a matched sample of loan funds and commercial banks. The sample period is from 2019Q2 to 2020Q1. Columns (1) to (3) measure the percentage of liquid assets, which is the sum of cash, cash equivalents, and Treasury securities. Columns (4) to (6) measure the percentage of corporate loans. Post is a dummy variable equal to one in 2020Q1 and Treat is a dummy variable equal to one for loan funds. The sample is matched by constructing a propensity score based on the portfolio weights of cash, government bonds and corporate loans. Standard errors in brackets are clustered by quarter. Data source: Morningstar and Call Reports.
Table 5: Portfolio Composition: Bank Loan Funds versus Banks (Robust)

<table>
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<tr>
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<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liquid</td>
<td>-1.933***</td>
<td>-1.512***</td>
<td>-1.933***</td>
<td>2.471**</td>
<td>1.877**</td>
<td>2.471**</td>
</tr>
<tr>
<td>[0.304]</td>
<td>[0.317]</td>
<td>[0.304]</td>
<td>[0.626]</td>
<td>[0.579]</td>
<td>[0.626]</td>
<td></td>
</tr>
<tr>
<td>Post*Treat</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bank/Fund F.E.</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Time F.E.</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Observations</td>
<td>623</td>
<td>623</td>
<td>623</td>
<td>623</td>
<td>623</td>
<td>623</td>
</tr>
<tr>
<td>Adj. R-squared</td>
<td>0.826</td>
<td>0.032</td>
<td>0.826</td>
<td>0.968</td>
<td>-0.004</td>
<td>0.969</td>
</tr>
</tbody>
</table>

This table presents difference-in-difference estimates of portfolio composition in a matched sample of loan funds and commercial banks. The sample period is from 2019Q2 to 2020Q1. Columns (1) to (3) measure the proportion of liquid assets, which is the sum of cash, cash equivalents, and Treasury securities. Columns (4) to (6) measure the proportion of committed corporate loans, which is the sum of loans outstanding and unused commitments. Post is a dummy variable equal to one in 2020Q1 and Treat is a dummy variable equal to one for loan funds. The sample is matched by constructing a propensity score based on the portfolio weights of cash, government bonds and corporate loans. Standard errors in brackets are clustered by quarter. Data source: Morningstar and Call Reports.
<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
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<td>Govt</td>
<td>IG</td>
<td>HY</td>
<td>BL</td>
<td>MS</td>
</tr>
<tr>
<td>Treasury Bond (Mar 15)</td>
<td>-0.019</td>
<td>-0.193***</td>
<td>-0.131***</td>
<td>-0.124**</td>
<td>-0.157***</td>
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<td>[0.059]</td>
<td>[0.042]</td>
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<tr>
<td>Corp Bond (Mar 23)</td>
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<td>0.052</td>
<td>0.111**</td>
<td>0.149**</td>
<td>-0.037</td>
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<td>[0.048]</td>
<td>[0.060]</td>
<td>[0.028]</td>
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<tr>
<td>Corp Bond Expansion (Apr 9)</td>
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<td>0.067*</td>
<td>0.133**</td>
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<td>0.012</td>
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<tr>
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<td>[0.021]</td>
<td>[0.036]</td>
<td>[0.058]</td>
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<td>[0.015]</td>
<td>[0.014]</td>
<td>[0.009]</td>
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<td>Yes</td>
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<td>Adj. R-squared</td>
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<td>0.076</td>
<td>0.068</td>
<td>0.092</td>
<td>0.068</td>
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</table>

This table presents panel regressions of daily fund flows (in %) on announcements of Federal interventions. Treasury Bond refers to the announcement of buying at least $500 billion in Treasury securities and $200 billion in government-guaranteed mortgage-backed securities on March 15; Corp Bond refers to the March 23 announcement of the Primary Market Corporate Credit Facility (PMCCF) and the Secondary Market Corporate Credit Facility (SMCCF); and Corp Bond Expansion refers to the April 9 announcement on raising the cap to $850 billion and the inclusion of high-yield bonds that were investment grade as of March 22. The event window is three days following the announcement. The sample period is from January 1, 2020 to April 30, 2020. Columns (1) to (5) correspond to fund flows for investment grade, high yield, bank loan, government, and multi-sector funds, respectively. The standard errors in brackets are clustered by time. Infection growth is defined as the daily growth rate of confirmed Covid-19 cases in the US since total cases exceeded 100. The data is obtained from https://usafacts.org/visualizations/coronavirus-covid-19-spread-map/
<table>
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<td>HY</td>
<td>BL</td>
<td>MS</td>
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<tr>
<td>Treasury Bond (Mar 15)</td>
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<td>-2.472***</td>
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<td>[0.548]</td>
<td>[0.478]</td>
<td>[0.221]</td>
</tr>
<tr>
<td>Corp Bond Expansion (Apr 9)</td>
<td>0.557***</td>
<td>1.904***</td>
<td>2.377***</td>
<td>1.264***</td>
<td>0.939***</td>
</tr>
<tr>
<td></td>
<td>[0.037]</td>
<td>[0.074]</td>
<td>[0.115]</td>
<td>[0.077]</td>
<td>[0.036]</td>
</tr>
<tr>
<td>Infection growth</td>
<td>-1.085***</td>
<td>-1.836***</td>
<td>-1.540</td>
<td>-1.051</td>
<td>-1.126***</td>
</tr>
<tr>
<td></td>
<td>[0.254]</td>
<td>[0.684]</td>
<td>[1.121]</td>
<td>[0.889]</td>
<td>[0.276]</td>
</tr>
<tr>
<td>Fund fixed effects</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Month fixed effects</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Observations</td>
<td>26,959</td>
<td>12,104</td>
<td>30,850</td>
<td>14,609</td>
<td>113,897</td>
</tr>
<tr>
<td>Adj. R-squared</td>
<td>0.048</td>
<td>0.144</td>
<td>0.184</td>
<td>0.213</td>
<td>0.069</td>
</tr>
</tbody>
</table>

This table presents panel regressions of daily percentage changes in fund NAVs on announcements of Federal interventions. Treasury Bond refers to the announcement of buying at least $500 billion in Treasury securities and $200 billion in government-guaranteed mortgage-backed securities on March 15; Corp Bond refers to the March 23 announcement of the Primary Market Corporate Credit Facility (PMCCF) and the Secondary Market Corporate Credit Facility (SMCCF); and Corp Bond Expansion refers to the April 9 announcement on raising the cap to $850 billion and the inclusion of high-yield bonds that were investment grade as of March 22. The event window is one day following the announcement. The sample period is from January 1, 2020 to April 30, 2020. Columns (1) to (5) correspond to NAVs of investment grade, high yield, bank loan, government, and multi-sector funds, respectively. The standard errors in brackets are clustered by time. Infection growth is defined as the daily growth rate of confirmed Covid-19 cases in the US since total cases exceeded 100. The data is obtained from https://usafacts.org/visualizations/coronavirus-covid-19-spread-map/.

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A Proofs

Proof of Proposition 1. We consider two exhaustive cases below.

Case 1: $l_x > 0$ and $l_y = 0$. Note that equations (3.4) and (3.5) give two ways to calculate $NAV_1$:

$$NAV_1(\lambda) = 1 - \frac{\phi_x l_x^2}{2 x}$$
$$= \frac{1}{\lambda} \left( l_x - \frac{\phi_x l_x^2}{2} \right), \quad (A.1)$$

where (A.1) uses $x + y = 1$. Solving (A.2) as an equation of $\lambda$ yields:

$$1 - \lambda = \frac{1 - l_x}{1 - \phi_x l_x^2}. \quad (A.3)$$

Plugging (A.3) into the expression of $NAV_2$ (3.6):

$$NAV_2(\lambda) = \frac{x - l_x + y R}{1 - \lambda}$$
$$= NAV_1(\lambda) \cdot \frac{x - l_x + y R}{x - l_x + y}, \quad (A.4)$$

where again (A.8) uses $x + y = 1$. Hence, $NAV_2(\lambda) > NAV_1(\lambda)$ if and only if $R > 1$ when $l_x > 0$ and $l_y = 0$.

Case 2: $l_x = x$ and $l_y > 0$. Similarly, by equations (3.4) and (3.5):

$$NAV_1(\lambda) = x - \frac{\phi_x x^2}{2} + y - (1 - \alpha) l_y - \frac{\alpha \phi_y l_y^2}{2}$$
$$= \frac{1}{\lambda} \left( x - \frac{\phi_x x^2}{2} + \alpha \left( l_y - \frac{\phi_y l_y^2}{2} \right) \right). \quad (A.5)$$

Solving (A.6) as an equation of $\lambda$ yields:

$$1 - \lambda = \frac{y - l_y}{x - \frac{\phi_x x^2}{2} + y - (1 - \alpha) l_y - \frac{\alpha \phi_y l_y^2}{2}}$$
$$= \frac{y - l_y}{NAV_1(\lambda)}. \quad (A.7)$$
Plugging (A.7) into the expression of \( NAV_2 \) (3.6):

\[
NAV_2(\lambda) = \frac{(y - l_y)R}{1 - \lambda} = NAV_1(\lambda) \cdot R ,
\]

thus again, \( NAV_2(\lambda) > NAV_1(\lambda) \) if and only if \( R > 1 \) when \( l_x > 0 \) and \( l_y = 0 \). 

\[\square\]

**Proof of Proposition 2.** The proof proceeds in three steps.

**Step 1:** We first solve for \( \bar{\pi} \), the amount of early redemption \( t = 1 \) that would exactly exhaust any given Treasury holdings \( x \), and show that reverse flight to liquidity occurs only when \( \pi \) is smaller than the cutoff \( \bar{\pi} \). Suppose \( \bar{\pi} \) early households redeem at \( t = 1 \) but no late household redeems. Conjecture that Case 1 in the proof of Proposition 1 occurs. By equations (3.4) and (3.5), we have

\[
\bar{\pi} NAV_1(\bar{\pi}) = x - \frac{\phi_x x^2}{2} \cdot \left(1 - \frac{\phi_x l_x^2}{2\phi_x x^2}\right) = l_x - \frac{\phi_x l_x^2}{2} ,
\]

which implies that \( l_x = x \) and verifies that Case 1 in the proof of Proposition 1 indeed happens. It also implies that \( \bar{\pi} \) early households redemption exhausts all the Treasury holdings \( x \). Hence, if \( \pi \geq \bar{\pi} \), the liquidation of Treasury holdings will not respond to any changes in fundamentals \( R \) regardless of late household redemption decisions. This implies that reverse flight to liquidity, if happens, will only happen when \( \pi < \bar{\pi} \) so that early household redemption would not completely exhaust the Treasury holdings at \( t = 1 \).

**Step 2:** We then show that when \( \pi < \bar{\pi} \), there exists a region of fundamentals \( [\bar{R}, 1] \) in which the fund liquidates Treasury to meet fundamental-driven redemption by late households, and consequently, reverse flight to liquidity occurs.

By Step 1, when \( \bar{\pi} - \pi \) late households redeem at \( t = 1 \), the fund exactly exhausts the Treasury holdings \( x \) due to both early and late household redemptions, and thus

\[
NAV_2(\bar{\pi}) = NAV_1(\bar{\pi})R
\]
according to (A.8). Solving late household’s problem (3.8) with respect to $R$ at \( w = \bar{\pi} - \pi \) yields:

\[
\hat{R} = 1 - \kappa (\bar{\pi} - \pi),
\]

which is strictly lower than 1. This implies that when \( \hat{R} < R < 1 \), the fund will only liquidate Treasury but not the project, leading to reverse flight to liquidity in this fundamental region.

Then, solving late household’s problem (3.8) again with respect to \( w \) immediately yields (3.9), in which \( \tilde{w}(R) \) is the only real solution to the following system:

\[
\begin{align*}
1 - \kappa \tilde{w} & = \frac{x - l_x + (1 - x)R}{1 - l_x}, \\
\tilde{w} \left(1 - \frac{\varphi_x}{x} l_x^2 \right) & = l_x - \frac{\varphi_x}{x} l_x^2.
\end{align*}
\]  (A.9)

Applying the Implicit Function Theorem to (A.9) immediately shows that both \( \tilde{w}(R) \) and \( l_x(R) \) are deceasing in \( R \), that is, more late households redeem when the fundamental is lower and it is accompanied by more liquidation of the Treasury.

**Step 3:** We finally characterize the liquidation values of both assets over the two fundamental regions \( R < \hat{R} \) and \( \hat{R} < R < 1 \). By Steps 1 and 2, it immediately follows that when \( \pi < \bar{\pi}, \hat{R} < R < 1 \) is well-defined, and the fund only liquidate the Treasury but not the project when \( \hat{R} < R < 1 \), whereas only liquidate the project when \( R < \hat{R} \), yielding (3.10) and (3.11). In particular, both \( \tilde{p}_x(R) \) and \( \tilde{p}_y(R) \) are increasing in \( R \) because they are decreasing in \( l_x \) and \( l_y \), respectively, both of which in turn decrease in \( R \).