The Imperfect Intermediation of Money-Like Assets*

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Abstract

We document a surprising amount of friction in the intermediation of money-like assets. From March 2022 to January 2023, 1-month T-bills returned 29 bps less than reverse repo with the Federal Reserve. We show that this large spread in money-like rates is due to segmentation and inelastic substitution by money funds. In a simple counterfactual, we show that if the money funds had elastically substituted between money-like assets, then the spread would have been 19 bps smaller. Inelastic substitution by investors is a general limit of "arbitrage", even for the simplest, lowest-risk and most transparent asset markets.

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1 Introduction

What is money? Money is defined by three characteristics: store of value, liquid, and a medium of exchange. As a store of value, money is absolutely safe. Money is liquid in that it is insensitive to information. Money is immediately useful in transactions.[1]

If we think these attributes are valued, then the most money-like assets should have the lowest yields. Consider the following three money-like assets: (i) central bank reserves; (ii) reverse repo with the Federal Reserve (RRP); and (iii) short-term Treasury bills (e.g. 1 month T-bills). According to our criteria, reserves are most money-like, followed by RRP, followed by T-bills. Reserves can be immediately used in settlement, while RRP has an overnight tenor. Unlike reserves and RRP, liquidating T-bills involves transaction costs and T-bills have duration risk.

However, from March 2022 to January 2023, yields were inversely related to the money-likeness of the three assets. On average, 1-month T-bills returned 29 bps less than RRP and RRP returned 10 bps less than reserves.

The spread between reserves and RRP can be explained by segmentation due to regulation. The Federal Reserve sets both the interest on reserves and the RRP rate and segments the market by only permitting banks to hold reserves. Bech and Klee (2011) explains how segmentation causes the interest on reserves to be higher than other market rates. Banks behaved in a manner consistent with reserves strictly dominating RRP. Despite having access to RRP, banks were at a near corner solution where they allocated nearly zero capital to RRP.

The RRP-bill spread is more puzzling. The purpose of the RRP program was to provide broad public access to Federal Reserve liabilities. Instead of only dealing with banks, the Federal Reserve permitted access to a "broad base of money market investors." If RRP was fully accessible, we would have expected T-bill rates to be higher than RRP rates.

In reality, RRP is only available to a set of money funds. Which brings us to central

[1] See Gorton (2017) for a literature review and historical discussion of money.

question we address in this paper: what are the frictions in the intermediation of money-like assets that can leave such a big spread between RRP and T-bills?

This large RRP-bill spread is at odds with the stated purpose of the RRP program to "provide a floor under overnight interest rates by acting as an alternative investment for a broad base of money market investors".[2] The premise is that making RRP available to money funds is de facto like making it available to "everyone", i.e., household and corporate sectors. This reflects the informal belief that money funds are a thin veil, and effectively a direct frictionless conduit to household and corporate sectors.

There are two broad mechanisms that can explain the tension between this informal logical and a large RRP-bill spread. First is segmentation. Corporate treasurers and households cannot directly participate in RRP, but they can directly hold bills. This segmentation is necessary but insufficient to create a wedge between RRP and T-bills. We also need that they do not sufficiently aggressively move money to money funds invested in RRP. In short, money funds are a sufficiently thick veil such that corporate treasurers and households do not elastically substitute between T-bills and money funds invested in RRP. Second, we also need that money funds are either constrained or do not elastically substitute to RRP when it has a higher yield than T-bills.

In this paper, we show that both mechanisms are significantly at play: segmentation and inelastic substitution by money funds. Capital flows into money funds are insufficiently sensitive to returns. The substitution from T-bills to RRP by money funds was entirely due to managerial rebalancing (within fund portfolio weights), rather than investor flows (across fund capital reallocation). Despite substitution by money funds from T-bills to RRP, money funds were at a deep interior point and continued to buy newly auctioned T-bills. When T-bills became scarce from March 2022 to January 2023, money funds were nearly perfectly inelastic to T-bills supply shocks.

We show in a simple counterfactual that even if money funds did substitute elastically

[2]This stated purpose of the RRP program is by the New York Federal Reserve: https://www.newyorkfed.org/markets/domestic-market-operations/monetary-policy-implementation/repo-rever

between RRP and T-bills, there would still have been a sizable spread in the period of T-bill scarcity. Elastic substitution by money funds would have increased the supply of T-bills by 0.2 trillion or about 6 percent of public supply. This increase in supply would have decreased the spread by 19 bps. However, there would have still been a sizable RRP-bill spread of 9 bps.

There are a surprising amount of frictions in intermediating money-like assets. These frictions reveal that investors are inelastic in substituting between money-like assets. This inelasticity is surprising because these money-like assets are near perfect substitutes and share a common marginal investor. The common frictions to intermediation discussed in the literature are less applicable to this setting. These frictions include specialized arbitrage capital (Shleifer and Vishny, 1997; Froot, 2001; He and Krishnamurthy, 2013; Duffie, 2010), balance sheet constraints (Du et al., 2018), and funding market frictions (Andersen et al., 2018). This suggests that inelastic substitution may be a more ubiquitous feature of financial markets than previously thought.

This inelastic substitution is a general limit of "arbitrage" and law of one price logic. We find frictions for the simplest, lowest-risk and most transparent asset markets. The more we look, the more we find arbitrage frictions in even the most unexpected places. Therefore, we cannot infer that the most money-like assets would have the lowest yields, even when they appear to be very broadly available. T-bill "specialness" is not just that it is the most money-like in the usual sense. Rather, T-bills are special because they are the most easily and broadly accessible money-like instrument. Additionally, there may be preferences for T-bills over other money-like assets that we do not fully understand. Money fund behavior hints at some of the latter, since they have full access to both RRP and T-bills and do not elastically substitute. Whether this preference generalizes to other types of investors is uncertain.

The surprising amount of friction in money funds intermediating money-like assets suggests that broader access to Federal Reserve programs may mitigate dispersion in short-term market rates. Direct access to the RRP for corporate treasurers and households might help, but

we cannot be sure. Investors may not substitute from T-bills to RRP just as they did not substitute from T-bills to money funds that were heavily invested in RRP.

These frictions to intermediation of near perfect, risk-free substitutes suggest that targeted interventions by policymakers may have limited spillover effects (Bernanke et al., 2004). However, the surprising granularity of these frictions highlights the importance of directly targeting the supply of the asset. We show that providing broad access to a near perfect T-bill substitute is insufficient to put a floor to short-term market rates.

2 Empirics

The empirical analysis proceeds as follows. We begin by documenting the realized and expected return differentials between different money-market instruments, focusing primarily on RRP and one-month T-bills. We then estimate how elastically money market funds with access to the Fed's RRP program substitute between RRP and T-bills in response to these return differentials. Finally, we ask how inflows from outside the money-fund sector respond to these same return differentials. Putting it all together, we are then able to conduct a counterfactual exercise in which we ask how spreads would have been different if money funds were perfectly elastic in their substitution between RRP and T-bills, as opposed to the imperfectly elastic substitution that we see in the data.

2.1 Money Rates

In Figure 1a, we plot the realized one-month returns associated with investing in three money-like assets over the period June 2021 to January 2023: (i) central bank reserves, (ii) overnight reverse repo with the Federal Reserve (RRP), and (iii) one-month T-bills.[3] We use one-month realized returns to match the tenor of the one-month T-bills, which is an important control because this is a period where interest rates are rising, and where the

[3]The data on money rates is from the New York Fed and Bloomberg.

quoted yield on the T-bills at any point in time might therefore exceed the two overnight rates simply due to expectations-hypothesis considerations.

As can be seen in the figure, in the "pre-period" interval from June 2021 to February 2022, realized returns on RRP and T-bills were almost exactly identical [1 bps difference] and 10 basis points below the returns on holding reserves. The behavior of spreads in this period is consistent with no scarcity of T-bills.

By contrast, from March 2022 through the end of the sample, T-bills return significantly less than RRP, with the average difference in realized returns being 29 basis points. This "post period" resembles meaningful scarcity in T-bills. From July 2021 to March 2022, the public supply of T-bills had decreased by about a quarter from 4.75 trillion to 3.60 trillion. In addition to T-bill scarcity, the post period features rising interest rates, which may have contributed to the emergence of the spread.

As we have emphasized, this behavior is superficially puzzling, given that RRP is if anything more money-like than one-month bills—it is equally immune from credit risk, has no duration risk, and is self-liquidating on a daily basis. It is this puzzling behavior that we are seeking to explain in what follows.

Figure 1b makes a similar point, but examines the difference between the expected, rather than realized returns on RRP and T-bills. To construct an expected one-month return on RRP, we take the current RRP rate, and add to it the spread between one month OIS and the current effective Fed Funds rate. This (OIS-Fed Funds) spread is meant to capture any expected increase or decrease in money market rates over the course of the month; again, the idea is to put RRP and bills on an equal footing and to control for expected changes in the stance of monetary policy.[4] Figure 1b also extends the sample period back to the inception of the RRP program in September 2013.

There are a few key takeaways from Figure 1b. First, in the post period starting in March 2022, the average spread in expected returns between RRP and bills is 32 basis points, very

[4]To be more precise, (RRP + OIS – Fed Funds) will be an exact proxy for the expected RRP rate if the spread between overnight RRP and overnight fed funds remains constant over the course of the month.

close to the 29 basis-point differential that we estimated in Figure 1a for realized returns. Thus our conclusion of a significant wedge between RRP and T-bills during the post period is not sensitive to the choice of an expected vs. realized returns metric. Second, over the longer interval from September 2013 to February 2022, the expected RRP-bills spread averages -1.6 basis points. This longer interval includes the previous rate hike cycle where the Fed Funds rate increased from 0.25 percent in December 2015 to 2.5 percent in December of 2018. Figure 1a shows that the RRP-bills spread was near zero during the previous period of rising interest rates. Rising interest rates did not previously cause the RRP-bills spread to widen.

2.2 Money Fund Holdings

Figure 2 shows the evolution of portfolio weights of those money funds with access to RRP, both for the shorter June 2021 to January 2023 period in Panel A, and for the longer periods starting in September 2013 in Panel B.[5] The six asset categories include Treasuries, RRP, reverse repo with the private sector, commercial paper and certificates of deposits, agency bonds, and other.[6]

From June 2021 to January 2023, Figure 2a shows how money funds substituted from Treasuries to RRP. Money funds decreased their portfolio weight in Treasuries from 39 percent to 11 percent, while they increased their portfolio weight in RRP from 19 percent to 44 percent. The portfolio weights in other categories remained qualitatively similar. Thus, RRP appears to be the closest substitute to T-bills for this period.

For a longer period starting in September 2013, Figure 2b shows how money funds have substituted more broadly between money-like assets. For example, the money fund reform of October 2016 caused significant substitution from private money (CP and CD) to government money (Treasuries, agencies, and repo) as described in Anderson et al. (2019). We also see a large substitution from repo to T-bills, following the large increases in the issuance of T-bills during Covid. During this period of plentiful T-bills, the RRP-Bill spread is on average

[5]The data is from Crane Data LLC.

[6]Other primarily includes Variable Rate Demandable Notes and unclassified assets.

negative -9 bps.

For both periods, Table 1a shows the average money fund's portfolio weight in T-bills by tenor (1-month, 3-month, 6-month and 1-year).[7] For the average money fund, the portfolio weight in 1-month T-bills decreased by 1.4 percent and the weight in 6-month T-bills decreased by 2.3 percent.

Compared to a longer history of T-bill holdings, the average money fund modestly decreased its T-bill holdings. These decreases were concentrated in T-bills with 6-months or less in maturity. For T-bills with between 6-months and 1-year in maturity, average holdings were unchanged. Overnight RRP is a closer substitute for shorter-dated T-bills. Table 1b shows how money funds with access to RRP changed their investments in newly issued T-bills. Money funds with access to RRP purchased 6.0 percent of auctioned 1-month T-bills in the pre-period and 4.7 percent in the post-period. Across all tenors, money funds decreased their purchases of newly issued T-bills by 4.2 percent of the total amount issued. Despite T-bill scarcity, money funds with access to RRP continued to purchase 9.1 percent of newly issued T-bills.

Although money funds decreased their average and marginal investments in T-bills, the substitution was surprisingly low. Money funds continued to buy T-bills rather than allocate funding to RRP despite a large RRP-bills spread of 32 bps. To understand whether money fund behavior was significantly different during this period of T-bill scarcity, we estimate substitution patterns across asset categories.

2.3 Money Fund Elasticity of Substitution

To characterize how money funds substitute between money-like investments, we estimate how portfolio weights change in response to the RRP-bills spread. We include the same categories of assets as in Figure 2b with the exception of splitting the Treasury category into

[7]The 1-month tenor denoted "1M" includes all T-bills with a tenor of less than or equal to 1-month. The 3-month tenor denoted "3M" includes all T-bills with a tenor greater than 1-month but less than or equal to 3-months. The 6-month and 1-year tenors are similarly defined.

T-bills and coupons. We estimate how portfolio weight ($w_{a,t}$) in asset a covaries with the RRP-bills spread:

$$\Delta w_{a,t} = \alpha_{\text{pre}} + \alpha_{\text{post}} + \beta_a \, \Delta\text{spread}_t + \gamma_a \, \Delta\text{spread}_t \times \text{post}_t + \epsilon_{a,t}. \tag{1}$$

For the pre-period, β_a is the sensitivity of substitution for asset a in response to the spread. For the post-period, $\beta_a + \gamma_a$ is the sensitivity of substitution. We use sensitivity of substitution and elasticity of substitution interchangeably.

Table 2 shows that for the pre-period, when the RRP-bill spread increases by 10 bps, money funds decrease their T-bill portfolio weight by 1.4 percent. Since the weights across asset categories sum to 1, the effect on the sum of other categories is positive 1.4 percent. In the post-period when T-bills are scarce, the sensitivity of substitution decreases by 75 percent. For the same 10 bps increase in the RRP-bill spread, money funds decrease their T-bill holdings by only 0.35 percent in the post-period.

The interpretation of these estimated sensitivities of substitution is complicated by endogeneity. The RRP-bill spread may widen either due to supply or demand shocks for T-bills. The estimated sensitivity of substitution is positively biased by money fund demand shocks for T-bills, which increase the spread and the portfolio weight in T-bills.

To address these endogeneity concerns, we instrument for the RRP-bill spread using changes in the private supply of T-bills. The Treasury auctions "bills on a regular and predictable basis" and does not tactically time the market (Garbade (2007)). This mitigates the exclusion restriction concern that the supply of T-bills increases precisely when the demand for T-bills is high.

We estimate the effect of percent changes in T-bill supply on the RRP-bill spread in units of basis points:

$$\Delta\text{spread}_t = \alpha_{\text{pre}} + \alpha_{\text{post}} + \beta_a \, \Delta\text{T-bill Supply}_t + \gamma_a \, \Delta\text{T-bill Supply}_t \times \text{post}_t + \epsilon_{a,t}. \tag{2}$$

Table 3a shows that for a 10 percent increase in the supply of T-bills, the RRP-bill spread decreases by 3.5 bps in the pre-period and 31 bps in the post-period (column 2). T-bill supply is a strong instrument with an F-stat of 13 and it explains up to 20 percent of the variation in the RRP-bill spread.

Using variation in the RRP-bill spread only due to T-bill supply shocks, we estimate the sensitivity of substitution for each asset category. Table 3b shows how the estimated sensitivities of substitution are much larger in response to exogenous variation in the RRP-bill spread.

In the pre-period, money funds decrease their holdings of T-bills by 12 percent in response to a 10 bps increase in the RRP-bill spread. Money funds predominantly substitute from T-bills into RRP, but other asset categories account for about 60 percent of the substitution. In the post-period, the sensitivity of substitution falls to near zero: the decrease in T-bill holdings falls from 12 percent to 0.7 percent. Furthermore, money funds predominantly substitute from T-bills to RRP. In the post-period, there is near zero substitution into other asset categories.

2.4 Frictions to Elastic Substitution

In the post-period, money funds in aggregate have become much more inelastic in their willingness to substitute from T-bills to other money-like assets. To explore the causes of this change in elasticity, we characterize cross-sectional heterogeneity in how money funds substitute and investors allocate capital across funds.

For each money fund, we estimate the sensitivity of substitution using the instrumented variation in RRP-bill spread from supply shocks. In the pre-period, for a 10 bps increase in the RRP-bill spread, the median fund decreased their T-bill holdings by 10 percent and a money fund at the 90th percentile decreased their T-bill holdings by 20 percent. In the post-period the distribution shifts to the right: money funds are much more inelastic in their substitution: the effect decreased to 0.33 percent for the median fund and 2.2 percent for the

fund at the 90th percentile.

This decrease in the aggregate elasticity of substitution in the post-period may be due to the negative T-bill supply shock changing the marginal investor or moving down the demand curve to a more inelastic region for the same marginal investor. Consider for example two money funds that hold T-bills and RRP, but the money funds differ in their elasticities of substitution. If the more elastic money fund substitutes until it holds zero T-bills, then the fund becomes constrained and the marginal investor switches to the more inelastic fund. Alternatively, the marginal investors may remain the same but as T-bill holdings decrease, the money funds become less willing to substitute.

Figure 3 shows a scatter plot of the elasticity of substitution for money funds in the pre-period and post-period. Note that the range of the post-period elasticities (y-axis) is much smaller than that of the pre-period, which is consistent with the broad decrease in the elasticity of substitution. However, the relative ordering of money funds tends to have remained the same. On average a fund that has a pre-period elasticity that is one standard deviation higher tends to have a post-period elasticity that is 0.35 standard deviations higher.

The aggregate decrease in the elasticity of substitution is primarily due to a move down the money fund demand curve for T-bills to a more inelastic region. Money funds were more elastic in their substitution between T-bills and other money-like assets when T-bills were not scarce. During the period of scarce T-bills, money funds were less willing to substitute to RRP even at large spreads.

Fund-level substitution between T-bills and other money-like assets does not account for investor flows. The aggregate money fund substitution from T-bills is composed of managerial flows (portfolio weight changes) and across-fund investor flows. Denote the assets under management (AUM) of each fund i by $\text{aum}_{i,t}$ and its weight in each asset category a by $w_{i,a,t}$. Define the change in the dollars invested in asset category a by fund i as

$$\text{Flow}_{i,a,t} = w_{i,a,t}\text{aum}_{i,t} - w_{i,a,t-1}\text{aum}_{i,t-1}.$$

We can decompose this flow into a component due to investor flows and managerial rebalancing. Since money funds invest in near-risk free assets and payout to maintain a stable net asset value of 1 per share, we measure investor flows as the change in fund AUM. To measure investor flows at the asset category, we assume that when investors allocate capital, they do so based on the observable one month lagged portfolio weights. Therefore, investor flows into asset category a are

$$\text{IFlow}_{i,a,t} = (aum_{i,t} - aum_{i,t-1})w_{i,a,t-1}.$$

The residual AUM flow of fund i into asset category a is due to managerial flows which we denote by:

$$\text{MFlow}_{i,a,t} = \text{Flow}_{i,a,t} - \text{IFlow}_{i,a,t}.$$

Figure 4 shows the counterfactual money fund portfolio weights without any managerial flows. We construct this counterfactual by subtracting the cumulative managerial flows from money fund holdings for each asset category. As documented in Anderson et al. (2019), we see that in response to the money fund reform of 2016, investors significantly reallocated capital away from fund invested in CP and CDs (prime funds) to funds invested in government securities and private repo (gov funds). However, we do not see significant investor flows from money funds invested in Treasuries to funds invested in RRP. The aggregate substitution of money funds from T-bills to RRP in the post-period, as shown in Figure 2b, happened entirely through managerial flows, not investor flows.

The lack of investor flows away from money funds with high T-bill portfolio weights to funds with high RRP portfolio weights appears to be at odds investors allocating capital in response to fund returns. We estimate the sensitivity of investor flows to lagged money fund returns:

$$\frac{\text{IFlow}_{i,t}}{\text{AUM}_{i,t-1}} = \alpha + \sum_{\tau=1}^{3} \beta_\tau \text{Ret}_{i,t-\tau}.$$

Table 5 shows that for a 1 bps increase in returns, money funds attract investor flows

that increase AUM by 4.8 bps over a quarter. This investor flow sensitivity is too small to discipline the dispersion in money-like rates. In response to a 10 bps RRP-bill spread, investors would only reallocate 48 bps of AUM from a fund entirely invested in T-bills to a fund entirely invested in RRP. This effect of investor flows is small compared to the 12 percent of substitution due to managerial flows in the pre-period (Table 3b).

2.5 Counterfactual and Discussion

Frictions to the elastic substitution of money funds between T-bills and other money-like assets contributed to the dearness of T-bills in the post-period. To evaluate the magnitude of this effect, we consider a counterfactual where money funds were much more elastic. In this counterfactual, money funds stopped purchasing T-bills in Dec 2021 and reinvested the proceeds of matured T-bills in RRP. Since RRP is a fixed rate set by the Federal Reserve, there are no indirect effects on the RRP-bill spread due to changes in the demand and supply of other money-like assets available to non-money fund investors in T-bills. Figure 5 shows the actual and counterfactual T-bill holdings of money funds. On average, money funds would have increased the supply of T-bills to the market by 0.2 trillion dollars.

The effect of increasing the supply of T-bills by 0.2 trillion on the RRP-bill spread depends on the aggregate market's elasticity of demand. The aggregate elasticity of demand is the market share weighted average elasticity demand of T-bill investors. In the counterfactual, we change the money funds' elasticity of demand for T-bills to 0. This decreases the aggregate market's elasticity for bills. money funds on average purchase 9.1 percent of newly auctioned T-bills in the post-period. Assuming the non-money fund elasticity remains the same, then this would cause the effect of a 1 percent increase in the supply of T-bills to change from -3.1 bps to -3.4 bps in the post-period (Table 3a).[8]

Increasing the supply of T-bills to non-money funds may increase the elasticity of non-money fund demand, which would decrease the impact on the RRP-bill spread. If T-bills

[8]For the post-period, the aggregate price multiplier for a 1 trillion dollar increase in the supply of T-bills is -3.05 bps. Excluding the demand of money funds increases the spread impact to -3.36 bps = -3.05 / (1-0.091).

became plentiful again, we may expect to revert to the pre-period elasticity, where a 1 percent increase in the supply of T-bills decreases the spread by 0.35 bps (Table 3a). However, 0.2 trillion is unlikely to change the elasticity of demand by non-money funds because 0.2 trillion is small compared to the 3.44 trillion outstanding private supply of T-bills as of Dec 2021. Furthermore, a 0.2 trillion increase in supply is small compared to the 1.3 trillion dollar decrease in the supply of T-bills from June 2020 to Dec 2021.

Figure 5b shows the counterfactual RRP-bill spread. In holding their T-bills to maturity and not buying any more T-bills, money funds would have increased the supply of T-bills by on average 0.2 trillion and the RRP-bill spread would have decreased by 19 bps. Despite this decrease, the average counterfactual RRP-bill spread is 9 bps, which is significantly higher than the pre-period historical average of -1.6 bps. Even with perfectly elastic substitution by money funds across money-like assets, T-bills would have been scarce.

The dearness of T-bills could have been mitigated by investors substituting from holding T-bills directly to indirectly holding RRP through money funds. However, this substitution would require investor flows from non-money fund investors who hold T-bills into funds who hold RRP. This is implausible because even money fund investors showed little to no propensity to substitute from funds with high T-bill holdings to funds with high RRP holdings.

These frictions to flows into money funds are evidence against money funds being a thin veil to household balance sheets. Whether this may be resolved by broader access to RRP is ambiguous. The same frictions may cause non-money funds to prefer to hold T-bills rather than directly invest in RRP.

We show that market participants are inelastic in their substitution between money-like instruments that appear to be near perfect substitutes. This inelasticity of substitution and sluggish investor flows can explain large spreads of about 40 bps between money-like instruments.

References

Andersen, L., D. Duffie, and Y. Song (2018). Funding value adjustments. *The Journal of Finance 74*(1), 145–192. (Cited on page 4.)

Anderson, A., W. Du, and B. Schlusche (2019). Money market fund reform and arbitrage capital. *Working Paper*. (Cited on pages 7 and 12.)

Bech, M. L. and E. Klee (2011). The mechanics of a graceful exit: Interest on reserves and segmentation in the federal funds market. *Journal of Monetary Economics 58*(5), 415–431. (Cited on page 2.)

Bernanke, B., V. Reinhart, and B. Sack (2004). Monetary policy alternatives at the zero bound: An empirical assessment. *Brookings papers on economic activity 2004*(2), 1–100. (Cited on page 5.)

Du, W., A. Tepper, and A. Verdelhan (2018). Deviations from covered interest rate parity. *The Journal of Finance 73*(3), 915–957. (Cited on page 4.)

Duffie, D. (2010). Presidential address: Asset price dynamics with slow-moving capital. *The Journal of Finance 65*(4), 1237–1267. (Cited on page 4.)

Froot, K. A. (2001). The market for catastrophe risk: a clinical examination. *Journal of Financial Economics 60*(2-3), 529–571. (Cited on page 4.)

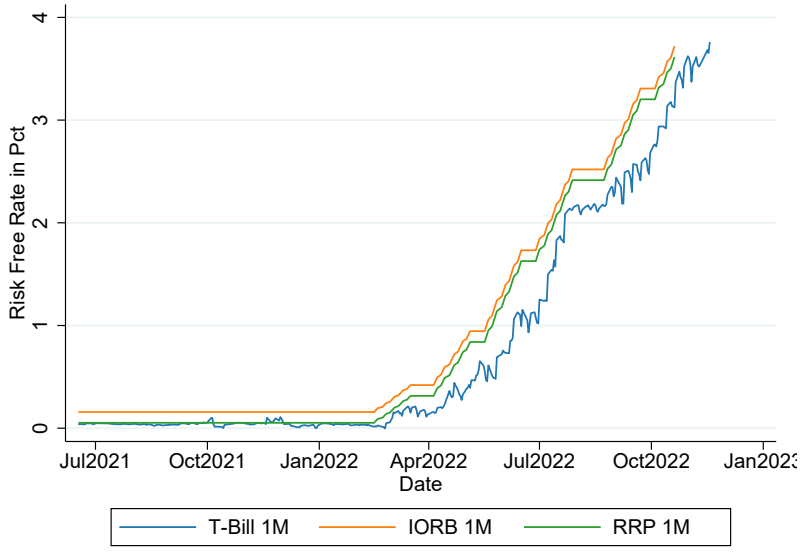
Garbade, K. (2007). The emergence of'regular and predictable'as a treasury debt management strategy. *Economic Policy Review 13*(1). (Cited on page 9.)

Gorton, G. (2017). The history and economics of safe assets. *Annual Review of Economics 9*, 547–586. (Cited on page 2.)

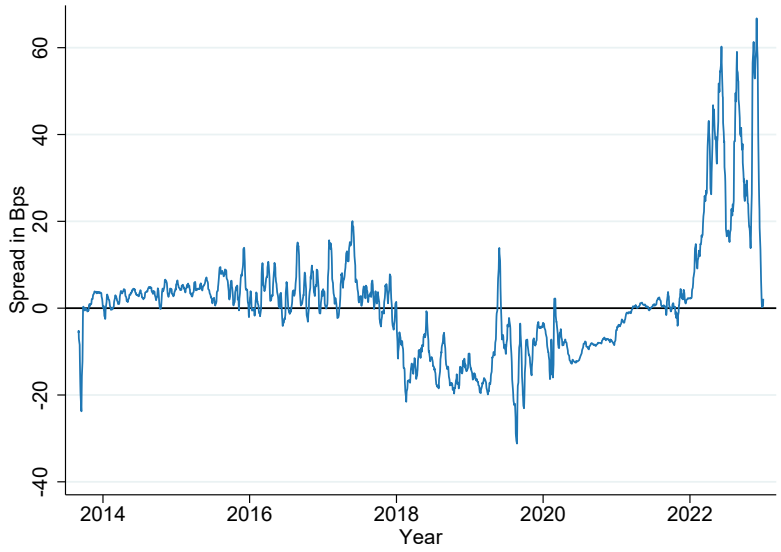
He, Z. and A. Krishnamurthy (2013). Intermediary asset pricing. *American Economic Review 103*(2), 732–770. (Cited on page 4.)

Shleifer, A. and R. W. Vishny (1997). The limits of arbitrage. *The Journal of Finance 52*(1), 35–55. (Cited on page 4.)

Figure 1: Realized and Expected Money Rates



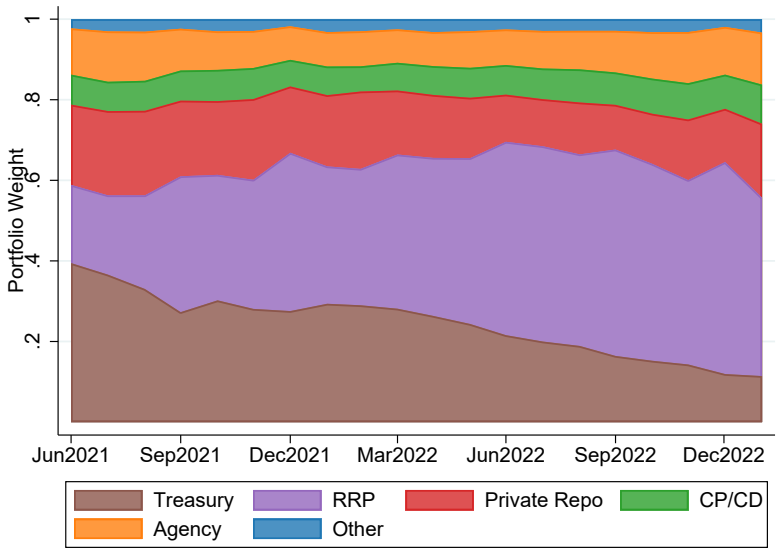
(a) Realized Money Rates (June 2021 - Oct 2022)



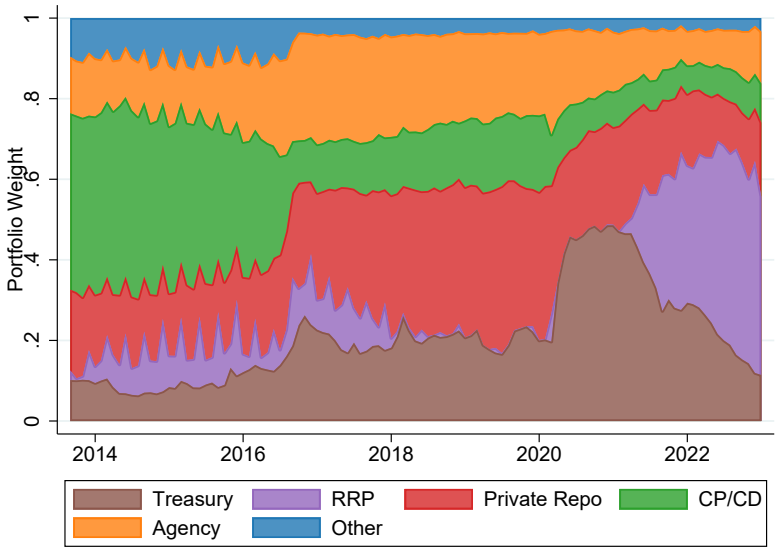
(b) T-Bill Spread (Sept 2013 - Oct 2022)

Notes: Panel A shows the realized 1-month annualized rates for Treasury bills (Tbill), Interest on Reserve Balances (IORB) and the Reserve Repo Program (RRP). Panel B shows the T-bill spread from Sept 2013 to Jan 2023 Where the T-bill spread is the 1-month OIS rate minus the 1-month T-bill rate minus the overnight spread between the Fed Funds and RRP rates.

Figure 2: MMF Portfolio Weights



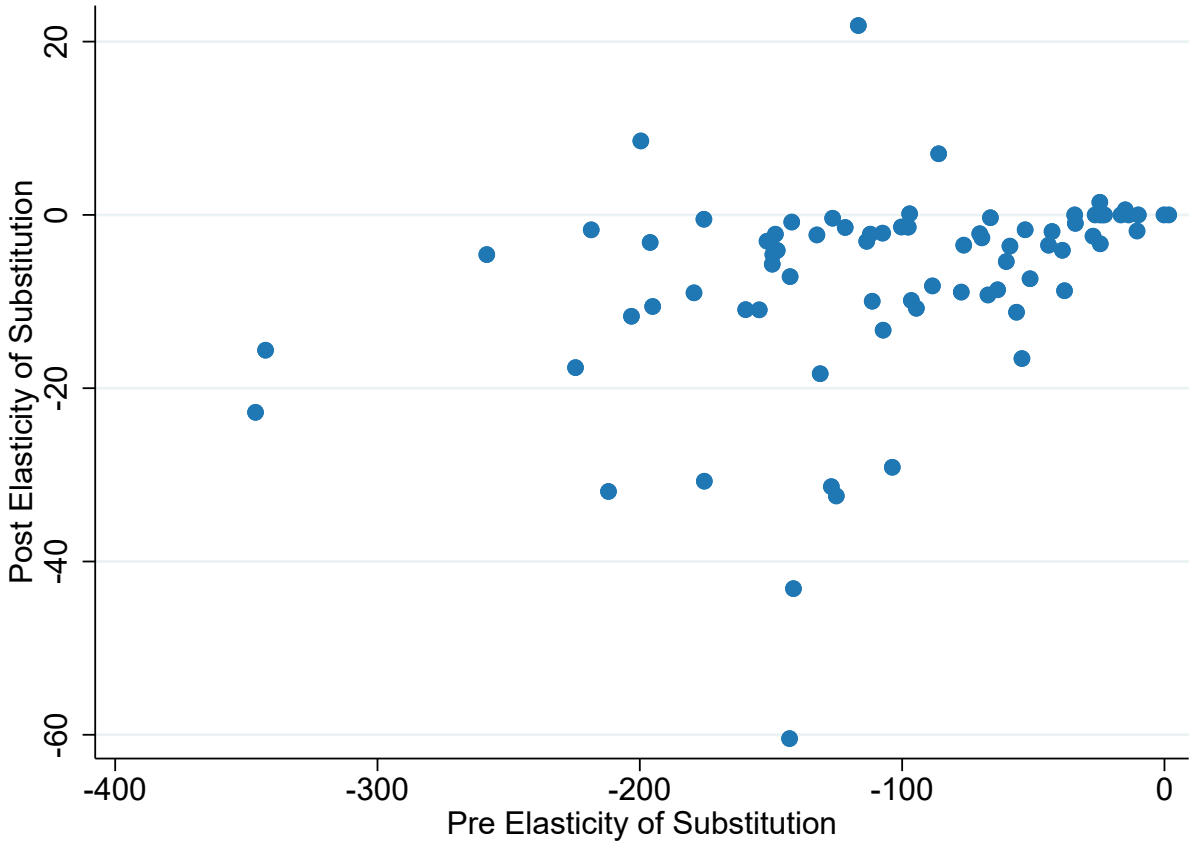
(a) June 2021 - Jan 2023



(b) Sept 2013 - Jan 2023

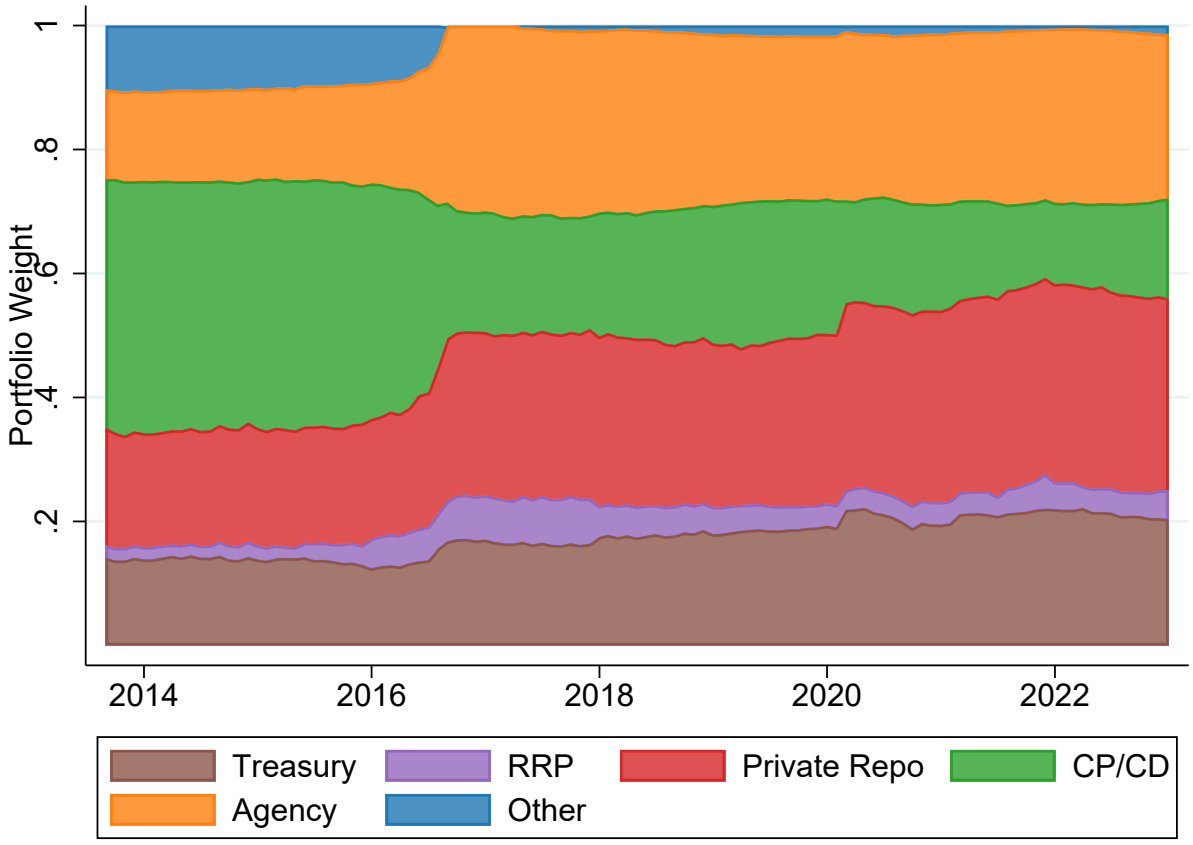
Notes: Panel A and B show the portfolio weights by asset class for all MMFs with access to the RRP facility. Panel A illustrates the portfolio weights for June 2021 to Oct 2022. Panel B shows the portfolio weights starting from the beginning of the RRP program: Sept 2013 to Jan 2023.

Figure 3: Fund Level Elasticity of Substitution



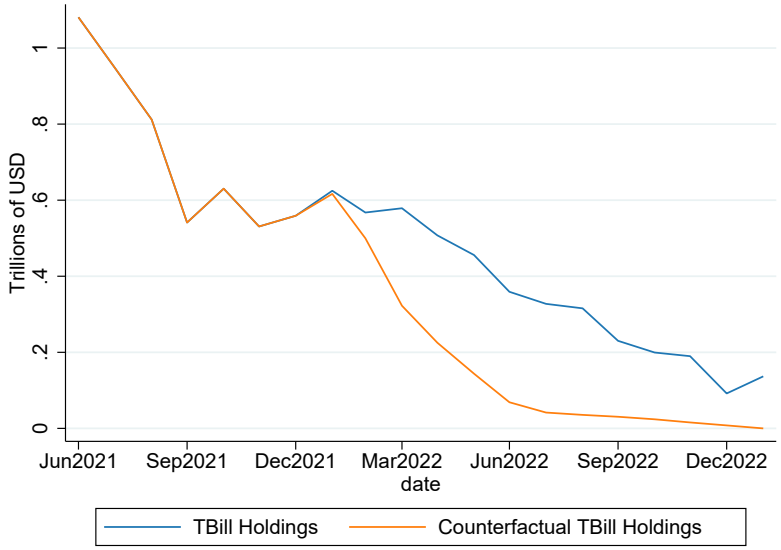
Notes: This figure shows a scatter plot of fund-level elasticities estimated in the pre-period (x-axis) and post period (y-axis). The pre-period is from Sep 2013 to Feb 2022 and the post-period is from Mar 2021 to Jan 2023.

Figure 4: MMF Investor Flow Portfolio Weights

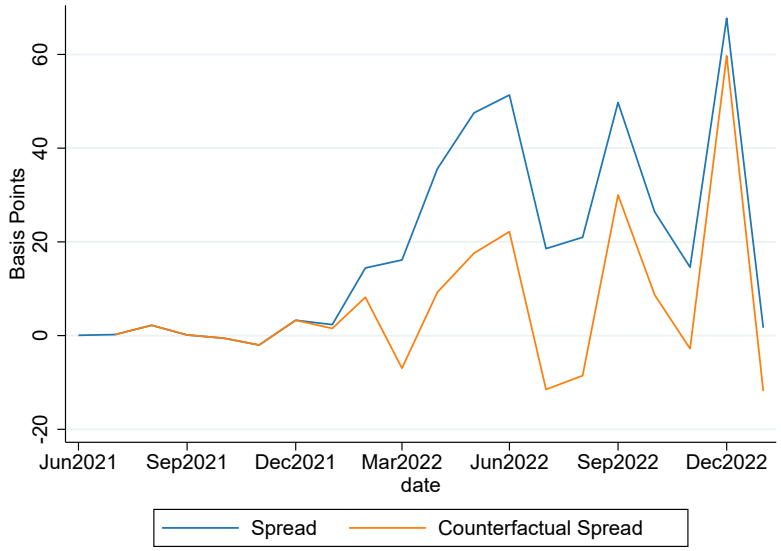


Notes: This figure illustrates aggregate MMF portfolio weights without any managerial rebalancing. Aggregate portfolio weights only change due to investor flows into funds with different asset weights. This figures shows the counterfactual aggregate MMF portfolio weights without any managerial flows.

Figure 5: Counterfactual T-bill Holdings of MMFs and the T-bill Spread



(a) T-bill Roll Off



(b) T-bill Spread

Notes: Panel A shows the actual T-bill holdings of MMFs with access to the RRP and the counterfactual holdings if no new T-bills were purchased after Dec 2021. In this counterfactual, there is an additional supply of on average 0.2 trillion T-bills for the market. Panel B shows the actual T-bill spread and counterfactual spread. Section 2.4 describes the counterfactual. The counterfactual 0.2 trillion dollar increase in the supply of T-bills would have decreased the spread by 19 bps.

Table 1: MMF Average and Marginal Holdings of T-bills

(a) T-bill Portfolio Weight

	Holdings		
Tenor	Pre	Post	Diff
1M	6.582***	5.161***	-1.422
	(0.85)	(1.52)	(1.05)
3M	11.484***	7.056***	-4.428***
	(1.16)	(1.21)	(0.71)
6M	6.886***	4.554***	-2.333***
	(0.33)	(0.40)	(0.41)
1Y	1.262***	1.260***	-0.003
	(0.09)	(0.12)	(0.14)

(b) MMF Share of Tbills Issued at Auction

	Net Purchases at Auction		
Tenor	Pre	Post	Diff
1M	6.04***	4.66***	-1.39***
	(0.26)	(0.46)	(0.53)
3M	12.51***	6.95***	-5.56***
	(0.40)	(0.53)	(0.66)
6M	20.22***	13.58***	-6.64***
	(0.64)	(1.34)	(1.48)
1Y	6.22***	7.29***	1.06
	(0.71)	(2.48)	(2.58)

Notes: Panel A shows the average portfolio weight of T-bills by tenor and period for MMFs with access to RRP ("Holdings"). The average MMF had 6.6 percent of their AUM invested in T-bills with a tenor of less than 1 month in the pre-period and 5.2 percent in the post period. The pre-period is from Sep 2013 to Feb 2022 and the post-period is from Mar 2022 to Jan 2023. Standard errors are clustered by fund.
Panel B shows the net purchases of T-bills by MMFs at auction as a percentage of quantity auctioned. Net purchases are defined as the change in the sum of MMF holdings of a T-bill CUSIP from month t to $t+1$ for which there is an auction for the T-bill CUSIP between months t and $t+1$. The panel reports net purchases divided by the issued dollar quantity of the T-bill CUSIP. Averages are reported where each observation is one T-bill auction. For the average T-bill auction of a tenors less than 1-month, MMFs with access to RRP in sum buy 6.0 percent of the issuance during the pre-period and 4.7 percent of the issuance during the post-period. Standard errors are robust.

Table 2: Elasticity of Substitution OLS

	Δ Portfolio Weight						
	Bills	RRP	Repo	Agency	CP	Coupons	Other
Δ Spread	-13.79***	32.45***	-13.88***	2.57	-4.95	2.15	-4.55*
	(4.42)	(8.70)	(4.82)	(2.76)	(3.07)	(1.50)	(2.52)
Δ Spread x Post	10.34**	-17.96*	6.68	-4.23	3.42	-0.93	2.67
	(4.52)	(9.77)	(5.43)	(2.87)	(3.12)	(1.58)	(2.66)
Post	-1.26***	0.73	-0.11	0.43**	0.67***	-0.55***	0.08
	(0.33)	(1.04)	(0.64)	(0.20)	(0.18)	(0.12)	(0.25)
Adjusted R^2	0.12	0.14	0.07	0.01	0.03	0.05	0.00
N	112	112	112	112	112	112	112

Notes: This table shows the OLS estimates of the elasticity of substitution by asset class in response to the T-bill spread ($spread_t$). The portfolio weight is the dollar weighted average portfolio weight of MMFs with access to RRP for asset class a ($w_{a,t}$). $post_t$ is an indicator variable equal to 1 after June 2021 and 0 otherwise. For each asset class, we estimate (1). The spread and weights are in units of percentage points. A 10 bps increase in the spread is associated with a 1.4 percent decrease in T-bill holdings during the pre-period and a 0.35 percent decrease in the post-period. Standard errors are robust and corrected for autocorrelation .

Table 3: Elasticity of Substitution - IV

(a) First Stage: Supply of Tbills

	Δ Tbill Spread	
	1	2
Δ T-bill Supply	-0.56***	-0.35***
	(0.15)	(0.10)
Δ T-bill Supply x Post		-2.70**
		(1.06)
Post		-0.01
		(0.05)
Adjusted R^2	0.07	0.20
N	112	112

(b) Elasticity of Substitution - IV

	Δ Portfolio Weight						
	Bills	RRP	Repo	Agency	CP	Coupons	Other
Δ Spread	-116.56***	50.33*	22.09	14.69	17.34	2.95	9.16
	(34.88)	(29.44)	(18.20)	(9.12)	(11.04)	(5.38)	(10.44)
Δ Spread x Post	109.89***	-20.94	-39.04**	-17.60*	-19.71*	-0.49	-12.12
	(34.93)	(30.17)	(18.72)	(9.18)	(11.06)	(5.43)	(10.49)
Post	-1.42*	0.81	-0.10	0.45*	0.70***	-0.54***	0.10
	(0.74)	(1.43)	(0.93)	(0.23)	(0.24)	(0.15)	(0.27)
N	112	112	112	112	112	112	112

Notes: Panel a shows the first stage of the instrumental variables estimation (see (2). A 10 percent increase in the supply of T-bills decreases the spread by 3.5 bps in the pre-period and 31 bps in the post period. Using the instrumented change in the T-bill spread, we estimate the elasticity of substitution for each asset category as in (1). A 10 bps increase in the spread due to a decrease in T-bill supply causes a 12 percent decrease in T-bill holdings during the pre-period and a 0.7 percent decrease in the post-period. Standard errors are robust.

Table 4: Elasticity of Substitution by Fund Type

	Elasticity of Substitution		
Type	Pre	Post	Diff
Retail	-104.460***	-8.216***	96.244***
	(14.28)	(2.27)	(13.38)
Institutional	-104.558***	-6.878***	97.681***
	(10.43)	(1.67)	(10.03)
GvtRet	-105.614**	-7.376**	98.238**
	(26.88)	(2.67)	(25.05)
GvtInst	-136.069***	-12.447***	123.622***
	(18.19)	(3.70)	(17.45)
PrmRet	-71.785***	-7.964*	63.821***
	(14.44)	(3.77)	(12.38)
PrmInst	-34.652***	-2.636***	32.016***
	(5.95)	(0.80)	(5.51)
TrsRet	-174.961***	-9.777	165.184***
	(27.91)	(5.94)	(26.31)
TrsInst	-155.753***	-5.108	150.645***
	(11.62)	(3.01)	(12.17)

Notes: This table shows the difference in the elasticity of T-bill substitution by fund type for the pre- and post-periods. Standard errors are clustered by fund.

Table 5: Investor Flow Return Sensitivity

	Investor Flow Pct			
	1	2	3	4
MMF Ret_{t-1}	1.07^{***}	2.05^{***}	3.06^{***}	2.34^{***}
	(0.10)	(0.47)	(0.60)	(0.67)
MMF Ret_{t-2}				2.22^{***}
				(0.53)
MMF Ret_{t-3}				0.22
				(0.52)
Time FE	N	Y	Y	Y
Fund FE	N	N	Y	Y
Adjusted R^2	0.01	0.05	0.06	0.06
N	9,519	9,519	9,518	9,106

Notes: This table estimates the sensitivity of investor flows to lagged MMF returns. Investor flows are measured as a percent of lagged fund AUM. MMF returns are measured as the dollar weighted average coupon on assets held by the MMF. A 40 bps increase in returns is associated with a 1.9 percentage points increase in AUM due to investor flows over a quarter (column 4).