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Abstract

This paper studies the mid-September 2019 stress in U.S. money markets: On September 16 and 17, unsecured and secured funding rates spiked up and, on September 17, the effective federal funds rate broke the ceiling of the Federal Open Market Committee (FOMC) target range. We highlight two factors that may have contributed to these events. First, reserves may have become scarce for at least some depository institutions, in the sense that these institutions' reserve holdings may have been close to, or lower than, their desired level. Moreover, frictions in the interbank market may have prevented the efficient allocation of reserves across institutions, so that although aggregate reserves may have been higher than the sum of reserves demanded by each institution, they were still scarce given the market's inability to allocate reserves efficiently. Second, we provide evidence that some large domestic dealers likely experienced an increase in intermediation costs, which led them to charge higher spreads to ultimate cash borrowers. This increase was due to a temporary reduction in lending from money market mutual funds, including through the Fixed Income Clearing Corporation's (FICC's) sponsored repo program.

Key words: federal funds market, repo market, central bank reserves, regulation, monetary policy

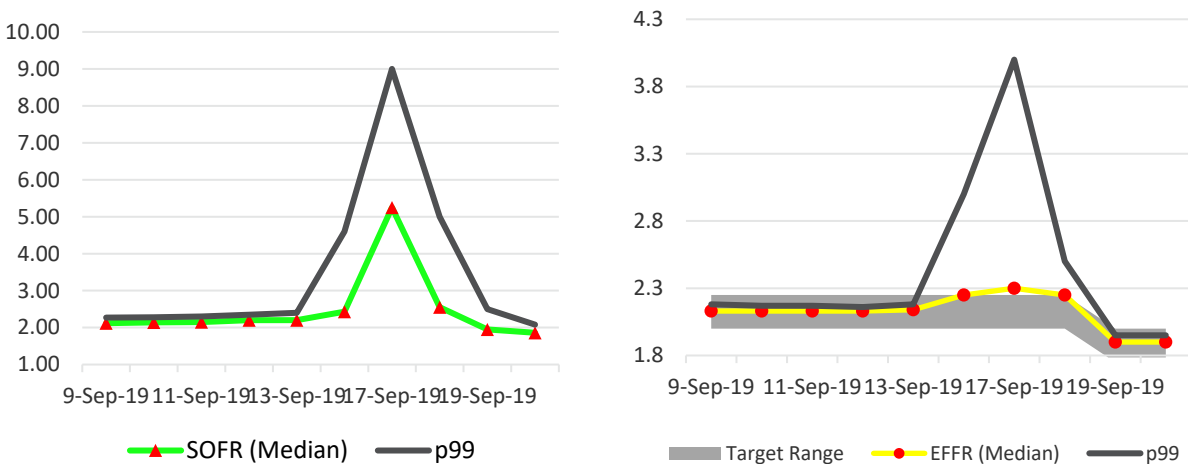
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1. Introduction

U.S. money markets unexpectedly experienced severe upward rate pressures on September 16 and 17, 2019. Several money market rates increased significantly. Notably, the secured overnight financing rate (SOFR), a measure of overnight funding cost in the Treasury repo market, increased by approximately 3 percent, printing over 5 percent and with its 99th percentile reaching 9 percent. The effective federal funds rate (EFFR) increased by a more modest amount, but there was a wide dispersion of rates in that market, and the EFFR exceeded the top of the FOMC's target range on September 17 (see Figure 1).

Figure 1



This episode attracted considerable attention among market practitioners, academics and policy makers, in part because it was unexpected. On September 16, two transitory shocks hit money markets: the quarterly corporate tax payment and the settlement of the mid-month Treasury coupon auction. Money market observers were well aware that the occurrence of both events on the same day would lead to a drop in the supply of reserves, a reduction in cash available to be lent in the repo market, and an increase in the demand for cash in that market. On their own, however, these two shocks do not provide a compelling explanation for what happened both because they were well anticipated and

because shocks of a similar type and magnitude had happened before without significant rate pressures.²

Analysts have pointed to long-lasting factors that could have interacted with the shocks mentioned above, or potentially with other shocks, to produce high rates. One notable example is the post-crisis Basel III regulation and the changes that such regulation, and the associated supervisory programs, caused to banks' risk management frameworks (see, for example, Covas and Nelson, 2019).

Long-lasting factors are not particularly helpful in explaining the events of mid-September 2019, unless it is possible to explain why they might have interacted with anticipated shocks in a manner that produces unexpected outcomes. Since Basel III regulation had been in place for some time, it is not clear why its effects on money markets would have been exacerbated in mid-September.

So what happened? In this paper, we highlight two factors that could have contributed to the mid-September stress in money markets. First, we argue that reserves may have become scarce, even though the overall supply of reserves was still large by historical standards. By reserves scarcity, we mean that reserve holdings of at least some depository institutions may have been close to, or lower than, their desired levels at rates near the interest on excess reserves (IOER) rate. Frictions that make it difficult or costly for banks to redistribute reserves among themselves can contribute to reserve scarcity. We show how reserves scarcity can help explain both the increase in the fed funds rate, directly, and the increase in the repo rate, indirectly.³

Second, we provide evidence that some large domestic dealers—who play an important intermediation role in the repo market—likely experienced a sharp increase of their intermediation costs in mid-September, leading them to increase the spread at which they intermediate. This cost increase was due to the temporary withdrawal of money market mutual funds from the Fixed Income Clearing Corporation's (FICC) sponsored repo program and may have led to an increase in repo rates more

² We use the term "shock" in the sense of a transient change in demand and/or supply that is unrelated to today's market conditions ("predetermined" in a time series analogy). In other words, something that is not affected by the actions of market participants today. This is different from the use of the term "shocks" as unexpected errors.

³ Schulhofer-Wohl (2019) also highlight the declining level of reserves as having likely contributed the observed rate pressures.

generally. We also briefly discuss other factors that may have contributed to the stress in money markets.

The remainder of the paper proceeds as follows: Section 2 provides an overview of the federal funds and the repo market. For each market, we describe the main participants and their relationships. We also describe how some participants are active in both markets and therefore provide a link between the two. Section 3 describes the anticipated shocks that hit money markets in mid-September. Section 4 explains how reserves scarcity and repo market frictions may have contributed to the stress. Section 5 describes the Fed's response to these events and Section 6 concludes.

2. A brief overview of the federal funds and repo markets

2.1. The federal funds market

Participants in the federal funds market trade uncollateralized loans, typically of overnight maturity, on a bilateral basis.⁴ Only institutions eligible to have a Federal Reserve account can trade fed funds. The main participants in this market are U.S. depository institutions (DIs), or “banks” for simplicity, U.S. branches and agencies of a foreign bank, and Federal Home Loan Banks (FHLBs). The EFFR is the weighted median of the interest rates on fed fund loans on a given day. The Federal Open Market Committee (FOMC) sets a target range for the EFFR to communicate the stance of monetary policy.

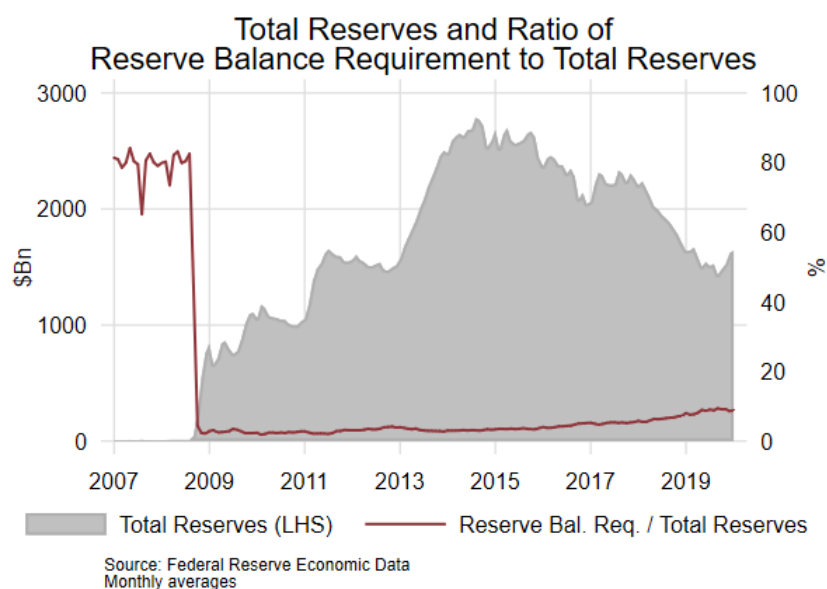
Before the crisis, the level of total reserves was in the tens of billions and the amount of reserves needed to meet reserve requirements constituted around 80% of total reserves (Figure 2). The fed funds market was mainly a market in which banks traded with each other in order to end the day with an amount of reserve just sufficient to satisfy their reserve requirements.⁵ Banks were careful not to hold more reserves than required so as not to lose the income from lending reserves. Hence, a bank holding fewer reserves than required would borrow from a bank holding more reserves than required.⁶

⁴ We use the terms federal funds and fed funds interchangeably.

⁵ Reserve requirements are the amount of funds that a depository institution is required to hold against specified deposit liabilities. For more detail see <https://www.federalreserve.gov/monetarypolicy/reservereq.htm>.

⁶ There is a rich literature that studies the fed funds market in the environment of scarce reserves as the one prior to the financial crisis. See Poole (1968), Furfine (1999), Martin et al. (2013), Ennis (2014), and Bech and Keister (2017) for models of the fed funds market as a centralized market; and Ashcraft and Duffie (2007), Berentsen and

Figure 2



Since the crisis, the level of reserves has increased massively, reaching \$2.8 trillion in 2014. This increase was mainly due to large-scale asset purchases by the Federal Reserve designed to stimulate the economy when short-term interest rates were very close to zero (Gagnon et al., 2011). As a result, most banks now hold more reserves than needed to satisfy reserve requirements, reducing the incentives for banks to trade with each other.⁷ Because of the high level of reserve and the reduced need to redistribute them across reserve-holding institutions, fed funds volume decreased from over \$100 billion on an average day in 2007 to under \$40 billion per day in 2015. The type of market activity underpinning fed funds transactions has changed too: in 2015, for example, in terms of dollar value, most fed funds transactions consisted of FHLBs lending to branches of foreign banks. The Federal Reserve has been able to maintain control of interest rates despite the large increase in reserves because Congress authorized it to pay interest on reserves in October 2008.⁸

Monnet (2008), Ennis and Weinberg (2013), and Afonso and Lagos (2015), among others, for models that capture the over-the-counter nature of the fed funds market.

⁷ Bech and Klee (2011), Armenter and Lester (2017), and Williamson (2018) study models of the fed funds market in an environment of abundant reserves. Afonso, Armenter, and Lester (2019) as well as Kim, Martin, Nosal (forthcoming) present a framework to study this market under both scarce and abundant reserves.

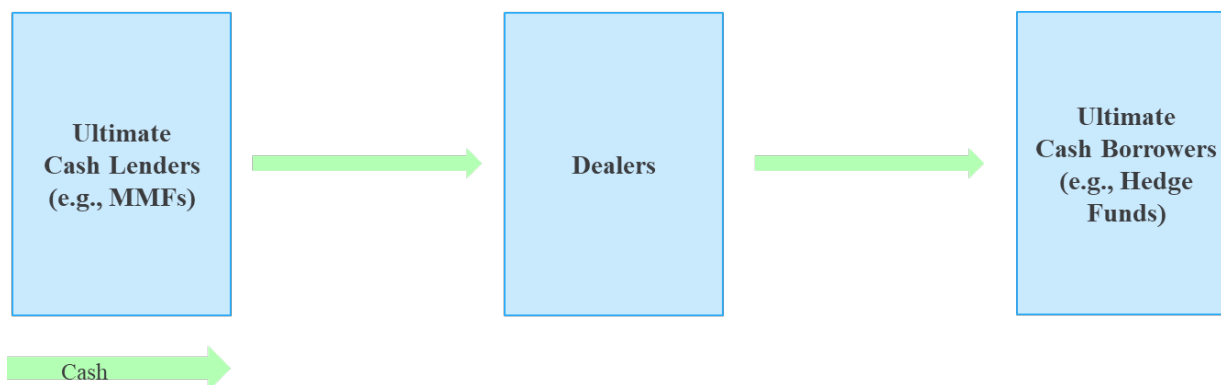
⁸ The Financial Services Regulatory Relief Act of 2006 authorized the Federal Reserve Banks to pay interest on balances held by or on behalf of depository institutions at Reserve Banks, subject to regulations of the Board of Governors, effective October 1, 2011. The effective date of this authority was advanced to October 1, 2008, by the Emergency Economic Stabilization Act of 2008.

As the FOMC began normalizing the stance of monetary policy, aggregate reserves declined to \$1.6tn in January 2019. As a result, fed funds volumes slowly increased to the current level of \$70-80 billion per day. The amount of interbank activity, however, remains low, at around 5% of total fed funds borrowing.

2.2. The repo market

Repo transactions are, in many respects, similar to collateralized loans. In this paper, we focus on overnight repo transactions collateralized by Treasuries, because it is the largest segment of the repo market and was central to the mid-September events.⁹

Figure 3



In the U.S., the repo market allows the transfer of cash from cash lenders, such as money market funds (MMFs), to cash borrowers such as hedge funds. As shown in Figure 3, broker-dealers (or dealers, for short) play a key role in that market as they intermediate between the ultimate cash lenders and borrowers. Dealers may be subsidiaries of bank holding companies with commercial banking subsidiaries that are DIs or may be stand-alone entities without affiliated commercial banks.¹⁰ Bank holding companies are supervised by the Federal Reserve, while stand-alone investment banks and broker dealers are not.

⁹ More specifically, we focus on general collateral (GC) repo transactions. In a GC repo, the lender does not require a specific security but is willing to accept any security within a predefined set.

¹⁰ Prior to the repeal of the Glass-Steagall Act, the activities of investment banks, such as broker-dealers, were separated from those of commercial banks. After the financial crisis of 2008, many of the largest investment banks became bank holding companies with a commercial banking subsidiary.

A significant share of dealers' intermediation activity is called "matched-book" intermediation. Strictly speaking, a dealer's book is "matched" if the maturity and collateral of a dealer's repo borrowing is the same as the maturity and collateral of its repo lending. In practice, dealers sometimes engage in maturity transformation—by lending at a longer term than the one at which they borrow—as well as collateral transformation—by lending against collateral of lower quality than the one against which they borrow. By intermediating, dealers earn the spread between their borrowing rate and their lending rate. In addition, some dealers can be net cash borrowers. This happens, for example, when they fund their proprietary inventory of securities in the repo market.

The market in which dealers primarily borrow cash from ultimate cash lender is the tri-party repo market. This market owes its name to the role played by a third party agent, Bank of New York Mellon (BNYM). BNYM provides a number services to market participants, including asset servicing, collateral management, and facilitating settlement.¹¹ In contrast, ultimate cash borrowers typically obtain cash in the bilateral repo market. In that market, cash investors and collateral providers perform a direct exchange, without the benefits of the settlement services of a third party.¹² Several institutions that borrow from dealers using repo contracts have few alternative options for funding; for this reason, their demand for repo funding is very inelastic, at least in the short run.

Figure 4 expands on Figure 3 by including a representation of the interdealer market. Interdealer repos backed by government securities are cleared by the FICC, which plays the role of central counterparty (CCP). CCPs reduce risk in the markets they clear by "novating" trades, becoming the buyer to every seller and the seller to every buyer. For example, if two members of a CCP, A and B, trade with each other, the CCP will replace the trade between A and B with two trades, one between A and the CCP and the other between the CCP and C.

The interdealer market has two components: the GCF Repo[®] market, which settles on the book of BNYM, like the tri-party repo market, and a bilateral market called the FICC DvP market, where DvP

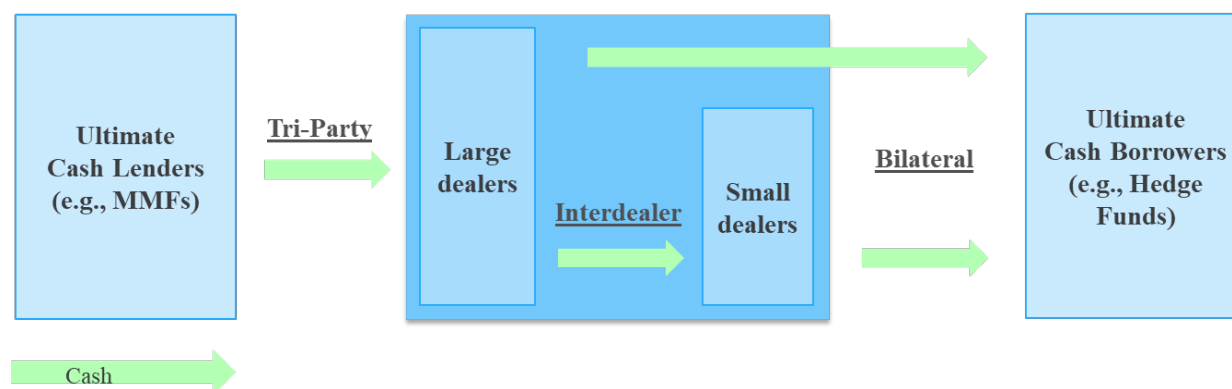
¹¹ See Copeland et al. (2012) for more detail on the tri-party repo market. In 2017, J.P. Morgan stopped serving the market as a tri-party clearing bank.

¹² Another difference between tri-party and bilateral repo markets is that the tri-party repo market is only used to finance general collateral (that is, any securities within a predefined set are accepted as collateral). Bilateral repo transactions, by contrast, allow for narrow restrictions on the securities eligible as collateral.

stands for “delivery versus payment.”^{13,14} Small dealers that borrow from large dealers in the interdealer market often on-lend to ultimate cash borrowers in the bilateral repo market.

The FICC sponsored program represents another way to lend or borrow cash in the interdealer repo market. The program started in 2005 but remained small until 2017, when it was expanded for the first time. Prior to the 2017 expansion, sponsored entities could only lend cash in the interdealer market; the expansion allowed these entities to borrow or lend cash. The program was expanded further in April 2019: whereas prior to that expansion, only custodial banks with \$5 billion in equity capital could be sponsors, the expansion created a second tier of potential sponsors, including broker dealers.

Figure 4



Under this service, a FICC member can sponsor institutions that satisfy the Qualified Institutional Buyer (QIB) standard.¹⁵ A sponsored institution, e.g., a MMF or a hedge fund, can access the interdealer market through their FICC member sponsor.¹⁶ In other words, the sponsored program extends access to clearing by FICC to a much larger set of financial institutions.

An important benefit of the sponsored program for dealers is that it increases trades’ eligibility for balance-sheet netting. For regulatory capital purposes, if a dealer lends and borrows through repos that

¹³ Like Tri-party, GCF Repo is a market for general collateral, whereas FICC DvP also allows for specific securities to be traded.

¹⁴ Because GCF repo settles on the book of BNYM, it is sometimes considered to be part of the tri-party repo market. For the purpose of this paper, it is more appropriate to exclude GCF repo from the tri-party market and consider it as part of the interdealer market.

¹⁵ A QIB is a purchaser of securities that is deemed financially sophisticated and is legally recognized by securities market regulators. The SEC sets requirements to qualify as a QIB.

¹⁶ The sponsor is responsible for guaranteeing the sponsored members’ activity to the FICC.

have the same maturity and the same counterparty, these exposures can be netted, even though the obligations between these participants have not been eliminated. This is however often not possible for a dealer running a matching book. Figure 5a illustrates a traditional matched-book trade, where B represents a dealer. The entity from which dealer B borrows cash, A, is different from the entity to which it lends cash, C; as a result, the two trades cannot be netted for regulatory capital.

By expanding access to FICC and allowing non-dealers to borrow or lend in the interdealer FICC DvP market, the sponsored program makes balance-sheet netting possible even when the cash lender or the cash borrower is not a dealer. This is illustrated in Figure 5b, where A and C represent entities sponsored by B, and the FICC is the CCP. After novation, A lends to FICC, C borrows from FICC, and B both borrows from and lends to FICC. The two transactions between B and the FICC can be netted from the balance sheet of B, reducing its regulatory burden.

Figure 5a.

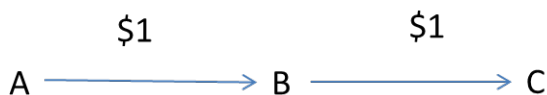
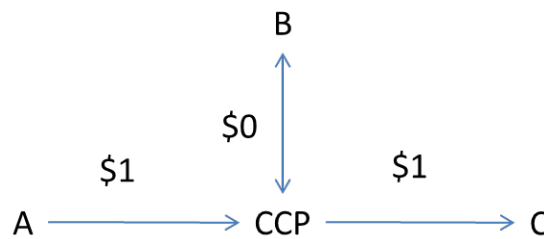


Figure 5b.



The reduction in intermediation cost faced by the dealers is likely to also benefit ultimate borrowers and lenders, as competition between dealers provides incentives for them to borrow at higher rates and lend at lower rates narrowing the bid-ask spread, to attract more business.

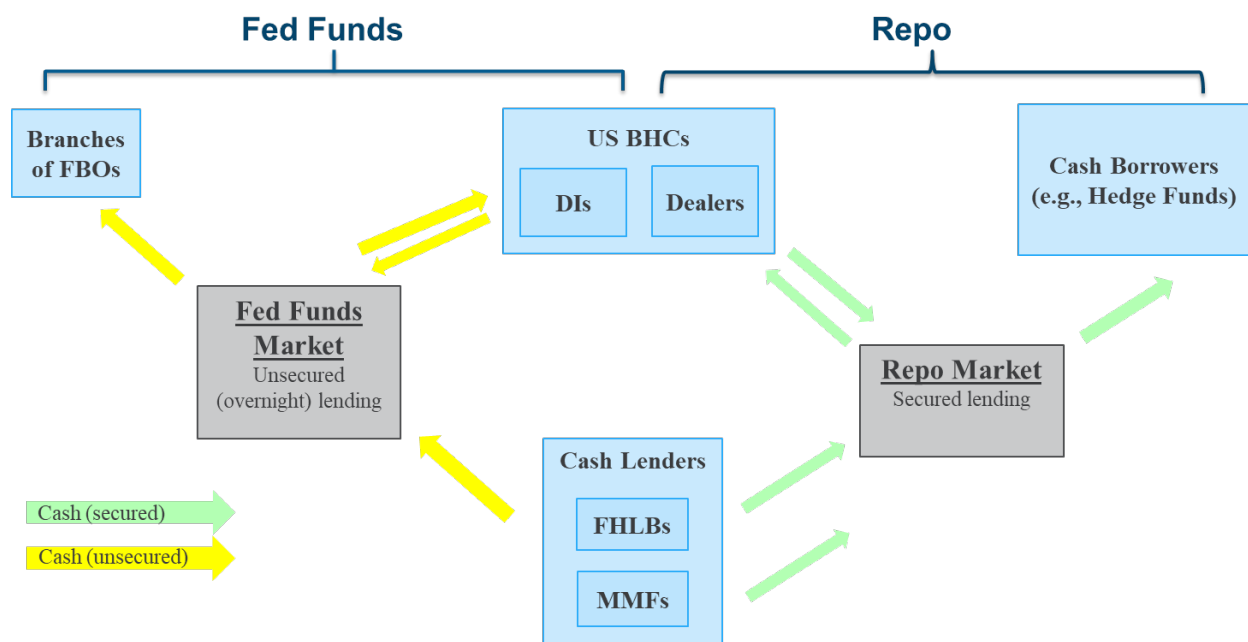
Under most circumstances, the sponsored program would support smooth repo-market functioning by reducing intermediation costs. This should be particularly true at quarter-ends, when some dealers must report a snapshot of their regulatory ratios. These dealers typically retreat from intermediating in the repo market because of the increased regulatory costs they face on these days. In principle, the sponsored program could reduce the need for these dealers to reduce their intermediation activity or could reduce the cost of other dealers' stepping in. Indeed, there is some evidence that a surge of

lending through the sponsored repo program helped mitigate repo market volatility at year-end 2019 (see Spratt, 2020). This surge is clearly visible in Figure 11 below.

2.3. Links between the federal funds and the repo markets

While fed funds and repo are separate markets, with distinct features, there are several links between the two. First, some lenders participate in both markets. For example, FHLBs have been the main lenders in the fed funds market since the 2007-2009 financial crisis. In the last few years, they have expanded their lending in the repo market. Hence, they can shift funds from one market to the other when rates in the two markets diverge. While MMFs cannot participate in the fed funds market, they can lend in the closely related Eurodollar market; hence, MMFs can also shift funds between secured and unsecured funding markets.

Figure 6



Second, some banks also participate in both markets. DIs, which are borrowers in the fed funds market, are typically not very active in the repo market. However, since April 2019, when repo rates increased consistently above IOER, an increasing number of DIs have been lending in the repo market to take advantage of attractive rates when the amount of reserves they hold is above their desired level (see

Avalos, Ehlers, and Eren 2019).¹⁷ Since some DIs and broker-dealers are both part of the same bank holding company, a DI could transfer funds to its dealer affiliate to lend in the repo market.

Figure 6 illustrates these particular interactions between the two markets. FHLBs can lend in both the fed funds and the repo market. Some DIs also have the capability to be active in both markets, either directly or through their dealer affiliate. The presence of these linkages is a channel through which shocks in one market can transmit themselves to the other.

3. What happened on September 16 and 17, 2019? – Two shocks

The events of September 16 and 17 coincided with payment of corporate taxes and the settlement of large Treasury issuance. In this section, we describe how corporate tax payments and Treasury issuance affect the fed funds and the repo markets and why that matters.

As noted earlier, fed funds borrowing transfers reserves to the borrowing banks. For that reason, changes to the supply of reserves affect conditions in the fed funds market. When a corporation makes a tax payment, cash balances move from the Fed account of a commercial bank to the Treasury General Account (TGA). For example, suppose corporation ABC holds cash in a deposit account at bank XYZ. To pay its taxes, corporation ABC instructs bank XYZ to make a payment on its behalf to the Treasury. Bank XYZ would do that by initiating a Fedwire® Funds transfer from its Fed account to the TGA. Balances in the TGA are not reserves. So, any transfer of balances from a bank's Fed account to the TGA results in a decrease in the aggregate level of reserves.

If corporation ABC holds its cash with an MMF, as is often the case, it would instruct the MMF to make the tax payment. The MMF, in turn, would instruct its custodial bank to make the payment to Treasury, similarly resulting in a decline in reserves.

A similar process occurs when the Treasury issues new securities. When newly issued securities are created, the vast majority are initially transferred to the securities account of Bank of New York Mellon (BNYM), the “clearing bank,” on Fedwire® Securities. As securities are transferred to BNYM's securities

¹⁷ More generally, some DIs borrow in the fed funds market and lend onwards in repo or FX swaps when these rates are sufficiently above rates in the fed funds market.

account, balances are transferred from BNYM's Fed account to the TGA. For the same reason mentioned above, this increases the balance of the TGA and decreases the aggregate level of reserves.¹⁸ The newly issued securities are subsequently transferred to the institutions and the individuals who purchased them, leading to movement of reserves between the Fed accounts of these institutions, or their custodians, and BNYM. These movements redistribute reserves among bank but, in contrast to transfers to the TGA, do not change the aggregate supply of reserves.

Furthermore, the payment of corporate taxes can affect the repo market by reducing MMF assets. Many corporate entities hold cash in the form of MMF shares. MMFs, in turn, lend this cash in the repo market. If a corporation pays its taxes by reducing its holdings of MMF shares, MMFs have less cash to invest in the repo market, which reduces the supply of cash available. Indeed, in Section 4.2, we show that MMFs respond to redemptions and subscriptions by adjusting their repo lending, which is to a large extent overnight. Moreover, the relationship between changes in MMF AUM and their repo lending has become stronger since the implementation of the SEC MMF reform in October 2016.¹⁹

Similarly, issuance of new Treasury securities affects the repo market by increasing the demand for cash by borrowers in that market. When Treasury issues new securities, dealers typically hold some amount of these securities in their inventories before they are able to sell them. During that time, dealers finance the securities in the repo market.

To summarize, while payment of corporate taxes and new Treasury issuance affect both the fed funds and the repo market, the effects are different in each market. In the fed funds market, both payment of corporate taxes and net Treasury issuance decrease the level of reserves. In the repo market, payment of corporate taxes decreases the supply of cash and new Treasury issuance increases the demand for cash.

It is worth noting that not all shocks affect both the repo and the fed funds market. Indeed, some shocks that influence the repo market may not affect the fed funds market and vice versa. If, for example, MMFs decide to hold more repos and fewer Treasury securities outright this would increase the amount

¹⁸ Maturing Treasury securities have the opposite effect and increase the supply of reserves. The overall effect on reserves is determined by the difference between new issuance and maturing securities.

¹⁹ For a description of the SEC reform and its impact on the MMF industry, see Cipriani and La Spada (2018).

of cash supplied in the repo market but would not affect the supply of reserves. Conversely, the decrease in the Fed's balance sheet reduced the level of reserves but did not necessarily change the supply of cash to the repo market. Specifically, as long as repo rates were below the interest paid on reserves, banks had no incentives to lend surplus reserves in the repo market; for that reason, any change in the reserve supply would have had no effect on the supply of cash in the repo market.

4. Interpreting what happened on September 16 and 17

One striking aspect of the events of mid-September is that the two shocks described above were anticipated and not exceptionally large. In this section, we discuss two potential factors that could help explain the unusually large response of interest rates: 1) reserve scarcity and 2) the increase in the intermediation cost of some large domestic dealers due to the outflow of funds supplied by MMFs from the sponsored repo program.

4.1. The role of reserve scarcity

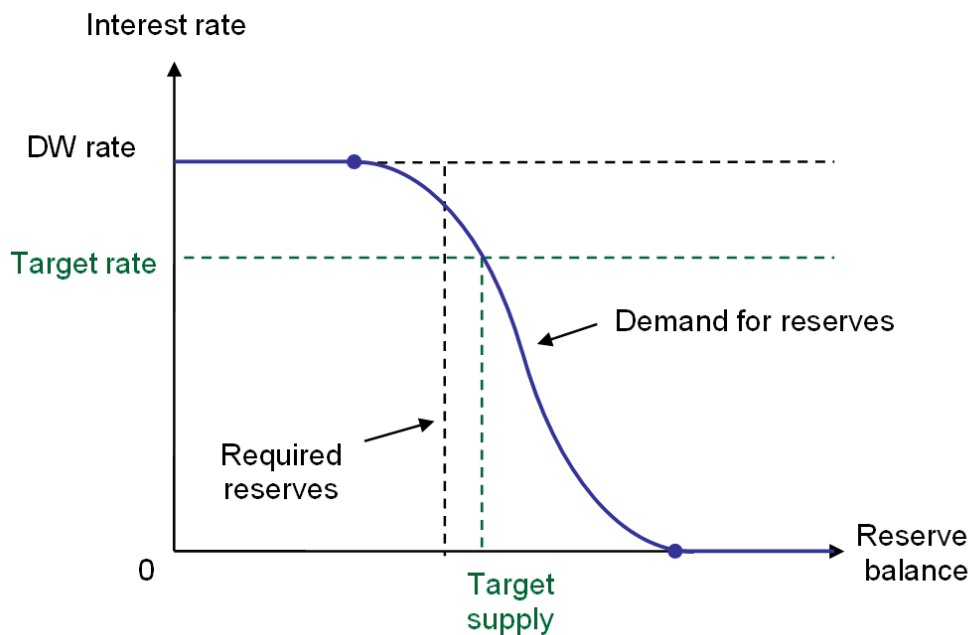
In this section, we focus on the role that reserve scarcity may have played in the events of mid-September 2019. By reserve scarcity, we mean that the reserve holdings of at least some depository institutions may have been close to, or lower than, their desired levels. To understand how reserves scarcity can affect the fed funds and the repo market, it is useful to provide a brief overview of how the Fed implemented monetary policy pre-crisis and how it has done so since the crisis.

As we mentioned above, pre-crisis, total reserves were very low, just a few 10s of billions of dollars. At the time, the demand for reserves was mainly determined by banks' reserve requirements. Since the Fed did not pay interest on reserves, banks would try to hold just enough reserves to satisfy their requirement, but not more, as holding unremunerated excess reserves had a high opportunity cost. This implies that the demand curve for reserves was quite steep around the level of required reserves and, as illustrated in Figure 7, small changes in the supply of reserves would result in significant changes in interest rates. To implement monetary policy, the New York Fed's Desk would adjust the supply of reserves through open market operations (i.e., by buying or selling governments securities) so that the

supply of reserves would intersect the demand curve for reserves at the interest rate target chosen by the FOMC.²⁰

As we discussed above, the supply of reserves increased dramatically at the end of 2008, as shown on Figure 2. The growth in reserves was mainly the result of large-scale asset purchases aimed at stimulating the economy and reached a peak of \$2.8 trillion in 2014. With the supply of reserves being so large, implementing monetary policy by relying on reserves scarcity became impossible, and the Federal Reserve had to think of a different framework.

Figure 7

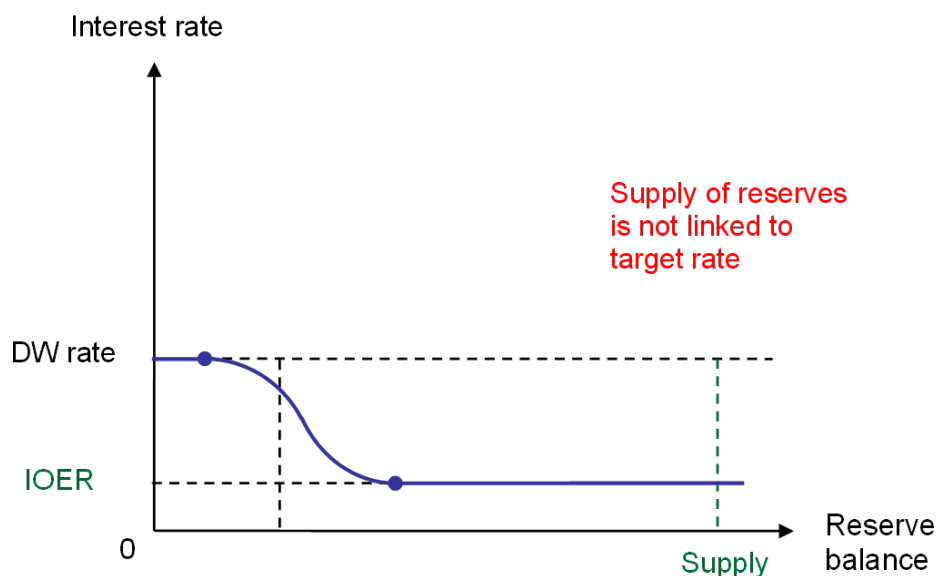


Congress granted the Federal Reserve the authority to pay interest on reserves in October 2008. As illustrated in Figure 8, at very high levels of reserves, the demand curve becomes flat around the level of the IOER rate. Indeed, when the amount of reserves is very high, relative to banks' needs, the main reason banks borrow reserves is to earn the spread between the borrowing rate and the IOER rate. And,

²⁰ Until December 2008, the FOMC would set a point target for the EFR. Since then, it sets a range.

as banks compete with each other, this spread should become small. As a result, when reserves are high, changes to the supply of reserves have very little impact on the fed funds rate.

Figure 8



In June 2017, the FOMC announced its plan to gradually reduce the size of its balance sheet by ceasing the reinvestment of proceeds from its maturing Treasuries and agency mortgage-backed securities, which led to the decrease in the supply of reserves that can be seen on Figure 2.²¹ Further, in January 2019, the FOMC announced that it “intends to continue to implement monetary policy in a regime in which an ample supply of reserves ensures that control over the level of the federal funds rate and other short-term interest rates is exercised primarily through the setting of the Federal Reserve's administered rates.”²² This could be interpreted as stating that that FOMC does not intend the supply of reserves to intersect the demand curve for reserves on the very steep part of the demand curve, as was the case pre-crisis.²³ The FOMC has also stated that the SOMA portfolio will hold no more securities than

²¹ For more detail, see <https://www.federalreserve.gov/monetarypolicy/policy-normalization-discussions-communications-history.htm>. The gradual reduction began in October 2017.

²² See <https://www.federalreserve.gov/newsevents/pressreleases/monetary20190130c.htm>.

²³ This interpretation is our own. For more detail on monetary policy implementation with ample reserves see Afonso et al. (2020).

necessary for efficient and effective policy implementation, which can be interpreted as suggesting that the supply of reserves will remain ample but close to the steep portion of the demand curve.

In the pre-crisis regime, the location of the steep part of the demand curve for reserves was well known, because it was mainly determined by banks' reserve requirements. By contrast, post crisis, the location of the steep part of the demand curve has become more difficult to gauge. The introduction of new liquidity regulations with Basel III and the associated supervisory programs have changed banks' liquidity management practices, fundamentally altering the banks' desired level of reserves. In a recent survey conducted by the Federal Reserve, the majority of bank respondents identified meeting routine intraday payments flows and satisfying internal liquidity stress metrics as main drivers of their demand for reserves.²⁴ This means that the level of reserves at which the demand curve becomes flat is likely much higher than it was pre-crisis. That level may also be more variable than pre-crisis, as the cost for DIs to redistribute reserves among themselves has increased and the set of factors driving reserve demand has broadened.²⁵

In mid-September 2019, the supply of reserves dipped below \$1.4tn, its lowest point since 2011. It is possible that the supply of reserves declined so much that it intersected the steep part of the demand curve for reserves. If that is indeed the case, then the increase in the fed funds rate on September 16 and, particularly, September 17 becomes easier to understand.

Figure 9 shows the supply of reserves during the first 20 days of September. Reserves declined \$65 billion on Monday, September 16, reaching their lowest level since 2011. While the decline was quickly reversed on September 17, the supply of reserves remained lower than it had been during the first half of September.

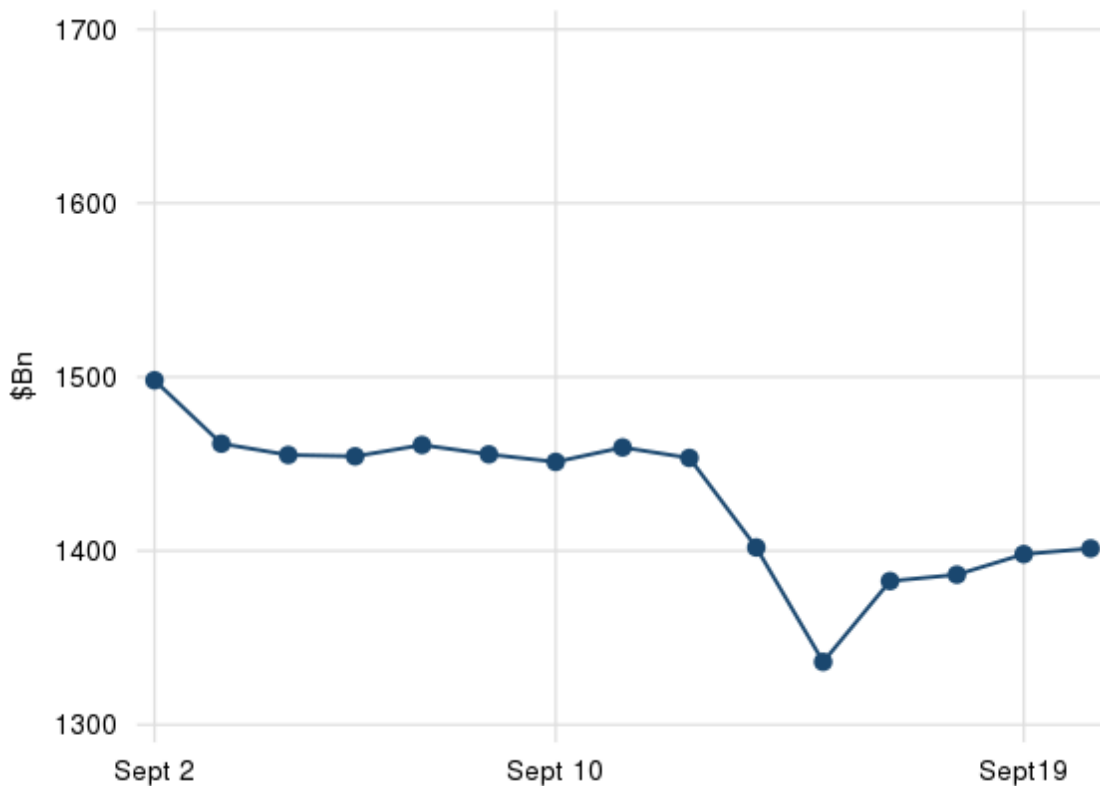
The fact that the EFR had been above IOER since April 2019 suggests that some banks were on the steep part of their individual demand curves. The sharp decrease in reserves observed in mid-September may have pushed some banks further up the steep part of their demand curves and could also have

²⁴ See the August 2019 Senior Financial Officer Survey, <https://www.federalreserve.gov/data/sfos/sfos.htm>

²⁵ Kim, Kyungmin, Antoine Martin, and Ed Nosal (forthcoming) study the impact of regulatory costs on interbank transactions. Afonso et al. (2020) discuss the relation between fed funds rates and reserve levels in the post-crisis period.

increased the number of banks that were on the steep part of their demand curves, leading to the observed increase in market rates.

Figure 9



While reserve scarcity could explain what happened in the fed funds market, it is not immediately clear why lower reserves and higher fed funds rates would create such a steep rate increase in the repo market. After all, the effective fed funds rate increased only by a few basis points, whereas the SOFR spiked by several percentage points. Additionally, as noted previously, the tax payments and Treasury issuance were not unusually large and similar shocks in the past had not led to large increases in repo rates.

One possible channel through which reserve scarcity may impact repo markets is the fact that some DIs lend in the repo market when repo rates are attractive, either directly or through their dealer affiliate. Avalos, Ehlers, and Eren (2019) document the importance of repo cash lending by depository institutions

f.²⁶ DIs, however, lend in the repo market only if they have more reserves than wish to hold minimum desired level. In previous instances where the repo market was buffeted by tax or Treasury issuance shocks, it is possible that enough DIs had sufficient reserves to lend in the repo market and offset rate pressures that would have otherwise happened.

Under this interpretation, reserve scarcity does not directly cause the spike in repo market. That spike is the result of the relatively small, anticipated shocks described above, namely, the decrease in the supply of cash and the increase in the demand for cash caused by the corporate tax payments and Treasury issuance. If the demand and supply for cash are sufficiently inelastic, even small changes in the supply and demand for cash could result in large interest rate increases. Reserve scarcity would only contribute to the spike in repo rates to the extent that it prevented banks from stepping in that market to mitigate the rate pressures (that is, as long as it renders the supply of repo cash inelastic). Anecdotal evidence suggests that, in September 2019, some banks did not have surplus reserves to lend. For example, during an earnings call on October 15, 2019, Jamie Dimon stated that JPMorgan could not lend more than it did in the repo market because of its internal reserves limits.²⁷ In addition, as we will show below, data on reserve levels and repo activity at banks also provide some evidence supporting the idea that reserves were scarce.

4.2. The role of intermediation costs

In this section, we describe how some large dealers experienced an increase in their intermediation costs in mid-September that may have contributed to the increase in repo rates. We try to answer three questions: First, abstracting from reserve scarcity, what else could explain the increase in repo rates in mid-September? Second, why were the rate increases so large? And, third, why did fed funds rates increase?

One set of circumstances that may have been unique to the mid-September events is the behavior of MMFs. As shown in Figure 10, from April to August 2019, government MMF assets under management (AUM) grew by \$264bn, resulting in an increase in Treasury-repo lending by MMFs of \$159bn. This AUM

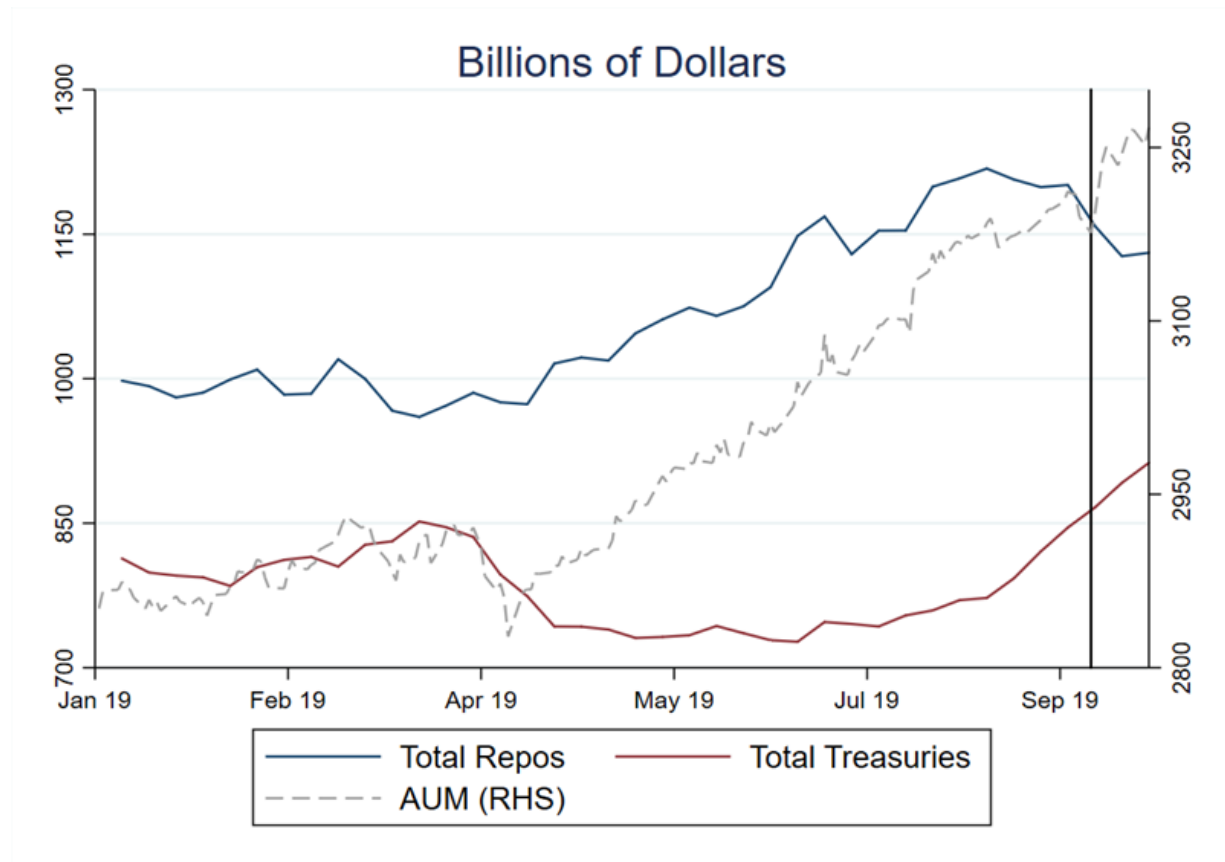
²⁶ See also Wrightson (2019).

²⁷ A transcript of the call can be found here: <https://www.fool.com/earnings/call-transcripts/2019/10/16/jpmorgan-chase-jpm-q3-2019-earnings-call-transcrip.aspx>.

growth is primarily due to the relative attractiveness of MMF yields given the low elasticity of banks' deposit rates to policy rate increases (see Cipriani et al., 2019, and Drechsler et al., 2017).

Since the SEC MMF reform was implemented, in October 2016, there has been a tight relationship between MMF AUM and MMF repo investment: the reason is that the reform increased the size of the Government MMF sector, which can only lend to the private sector through repo backed by Treasury or Agency securities. Since the SEC reform took effect, we estimate that on average, for every dollar change in AUM, repo investment changes by 0.69.

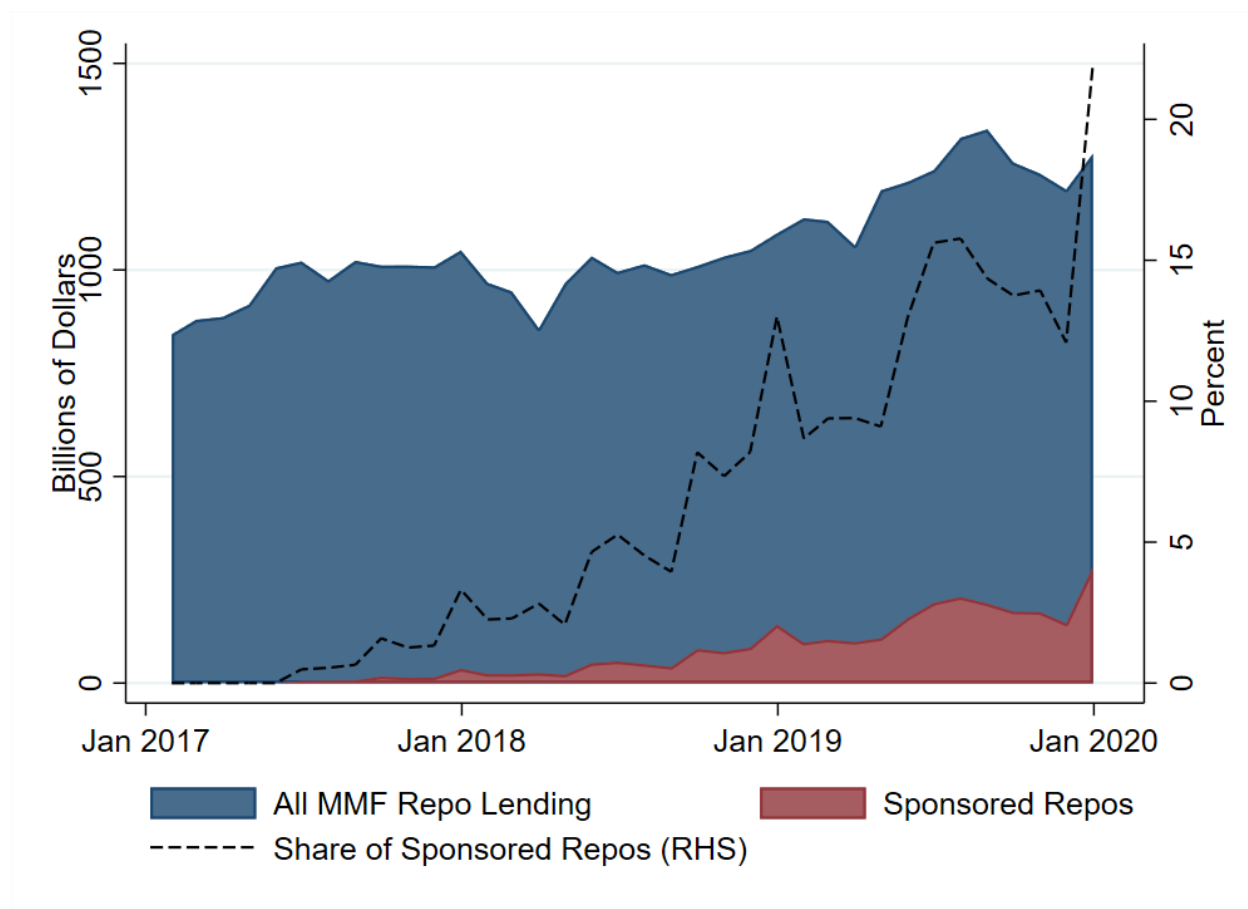
Figure 10



Since early August 2019, MMF repo lending started to decrease as MMFs shifted their portfolio into term instruments, primarily Treasury bills. The shift is related to higher expected returns from holding bills due to MMFs' expectation of monetary policy loosening at the FOMC's September meeting. Indeed, MMFs have historically increased weighted-average maturities ahead of expected rate cuts (Di Maggio and Kacperczyk, 2017; La Spada, 2018).

Importantly, during 2019, both the increase and subsequent decrease in MMF repo lending were mirrored in changes in the size of the FICC sponsored repo program, as shown in Figure 11, suggesting that the expansion and contraction in MMF repo lending occurred to a great extent in this segment of the repo market. MMFs may have preferred to reduce FICC sponsored repo lending, rather than their tri-party lending with large dealers because established relationships with dealers are important in the tri-party repo market. Sponsored repo, being a relatively new option, may not rely on relationships as much.

Figure 11



During the week of September 13-16, AUM of government and prime MMFs decreased by \$34bn, mainly coming from institutional funds, whose investors were affected by the corporate tax day. The decrease was similar to other recent corporate tax dates, both in magnitude and in the fact that it reverted in the following days. That said, repo lending by MMF contracted both on the week of the 16th (by \$43bn) and on the following week (by \$31bn). MMF repo investments saw a cumulative decline of

about \$60bn between August 20th and September 17th, the largest decrease since early 2018. It is important to remark that such decrease in repo lending by MMFs was larger than that implied by the estimated historical relationship between AUM and repo, suggesting that although the shock was expected, the resulting pull back by MMFs from repo lending may have been somewhat larger than anticipated.

How was the demand for cash met in the repo market after MMF retrenchment? Some of the domestic global systemically important banks (US GSIBs) stepped in. As cash lending into FICC coming from sponsored repo decreased due to MMFs pulling back, US GSIBs increased their net lending, essentially making up the shortfall, notably on September 16 and 17.

It is difficult to be sure where US GSIBs obtained the cash for their additional net lending. Total net repo borrowing across all repo markets declined for US GSIBs, suggesting that the source of additional cash is not coming from other repo markets. One possibility is that the additional cash lent came from affiliates of the US GSIBs, for example, their DIs, if they had more reserves than their minimum desired level.

The retrenchment of MMF funding from the sponsored repo program likely increased the average intermediation costs faced by institutions lending in the interdealer market. Indeed, as explained in section 1.2, funds borrowed through the sponsored program can be netted against fund lent in the FICC-cleared interdealer market. In contrast, funds obtained from other sources typically cannot. As a result, the MMF pull back likely increased the average intermediation costs of US GSIBs; that is, the additional regulatory cost of lending due to a loss in the ability to net. Put differently, the rate required for US GSIBs to increase their net lending in the repo market likely rose. We can see evidence of this intermediation-cost increase reflected in the interest rate spread between the rate at which US GSIBs borrowed in tri-party repo and the rate at which they lend in FICC DvP. This spread ticked up in the days leading up to September 17, before skyrocketing on September 17 itself. So, while US GSIBs likely saw their intermediation costs increase, they also were able to increase their intermediation margins.

The decrease in sponsored repo would not increase a dealer's intermediation cost if the dealer were able to redeploy surplus reserves from its DI affiliate. In this case, the repo loan would simply replace reserves on the asset side of the aggregated balance sheet of the bank holding company, leaving its size unchanged. This suggests a possible link between reserve scarcity and the repo channel highlighted in

this section. If reserves are sufficiently plentiful, institutions like GSIBs could increase their repo lending in the face of an MMF pull back from the sponsored program without seeing their intermediation cost increase.

While the MMF pullback from the sponsored repo program can help explain why repo rates increased more than expected, particularly in a context of scarce reserves, it is unlikely that these facts alone are enough to explain why the repo rates increased as much as they did. We now turn to some potential factors that could have exacerbated the rate movement.

Higher intermediation cost can explain an increase in the rate at which dealers lend but not necessarily the rate at which they borrow. So what explains that the rates at which dealers borrowed in the tri-party repo market increased? One possible explanation is the transmission of information across repo-market segments. Because the tri-party repo market is over-the-counter, one of the few sources of pricing information is interdealer screens. An unexpected rise in interdealer rates could have led tri-party lenders to ask for higher rates. Of course, since dealers must earn a spread, they would increase the rates at which they lend as a response to higher tri-party repo rates, leading to a vicious cycle triggered by the increase in intermediation costs described above.

Market observers have mentioned other factors that may have played a role in the mid-September stress, particularly on September 17, when signs of panic appeared in money markets. We discuss some of these explanations briefly. Some repo market lenders may have chosen to delay their lending in the face of larger-than-expected rate movements, waiting to obtain more information about the cause of the rate increase. For example, some market participants may have been concerned that the rate volatility was due to something other than a mere transient liquidity issue and may have preferred to hold on to their cash in case they might need it later. This type of behavior, not lending because liquidity is scarce and might be needed later, thereby exacerbating the scarcity, is typical of self-fulfilling liquidity panics.

Frictions related to bank's risk management framework may also have prevented some firms from reacting fast enough. Banks manage their liquidity more tightly than pre 2008 crisis, which means that they may have become slower or more reluctant in taking advantage of profit opportunities (such a liquidity driven mispricing) Responses the recent survey of Senior Financial Officer conducted by the

Federal Reserve mentioned above, are broadly consistent with this interpretation. Some form of approval is typically required to exceed a bank's internal liquidity limits and this may slow banks' response quickly to changing market condition. This, combined with the fact that the repo market trades very early, typically before 9 AM, could have made it difficult to deploy cash at short notice. We find some evidence suggesting that frictions related to banks' risk management frameworks and regulation may have played a role: indeed, BHCs that appear more constrained in their regulatory ratios lend at higher rates (and/or spreads).

Note that there is a distinction between the effects of regulation itself, the associated supervision, and the effect of the risk-management frameworks put in place by banks, either as a response to the regulation and supervision or based on lessons learned from the 2007-2009 financial crisis. In contrast to the suggestion of some market commentary, it seems unlikely that regulation itself may have been a key contributing factor to the money market stress of mid-September. Banks typically hold considerable buffers above their regulatory minima, which means that the regulatory constraints were, in all likelihood, not binding. However, even if regulatory constraints are not binding, it is possible that internal limits set by the banks themselves and in response to supervisory expectations may have been binding, at least for some banks.

Finally, some observers have suggested that market concentration may have played a role. For example, Smith (2019) interviews repo dealers who express concerns that a small number of cash lenders may have a stronghold on the market.

The last question we attempt to answer in this section is: Did the strains in the repo market outlined above impact the fed funds market? More precisely, if reserves had not been scarce, and the spike in repo rates were only due to the factors mentioned above, would have we observed an increase in fed funds rates?

One source of the spillover from repo to fed funds rates could be the behavior of FHLBs, which are the main cash supplier in the fed funds market and also lend in the repo market. Fed funds volumes were unusually low on Monday, September 16, which is consistent with FHLBs increasing their lending in the repo market and, correspondingly, decreasing the amount they lend in the fed funds market.

In addition, it appears that there was very little fed funds activity early on Tuesday as market participants, including FHLBs, may have delayed their lending, to assess the situation in money markets. FHLBs could also have chosen to wait to find out about potential liquidity draws from their members. This type of behavior could help explain the increase in fed funds rates during those days.

5. *The Federal Reserve's response*

In this section we briefly describe the Federal Reserve's response to the mid-September 2019 events and describe the effects of the Federal Reserve's operations on the fed funds and the repo markets. Then, we consider what this episode teaches us about the Federal Reserve's monetary policy implementation framework.

The Federal Reserve responded to elevated rates on September 16 and 17 by adding reserves through lending cash in the repo market, starting from September 17. In addition, starting in October, the Federal Reserve began to purchase Treasury bills outright to maintain a supply of reserve greater than the one that prevailed in early September.

In particular, the NY Fed's Desk announced an overnight repo operation shortly after 9 AM on Tuesday, September 17, as a response to upward pressure on the fed funds rate observed on the prior day, particularly in the afternoon. The operation had a maximum size of \$75 billion against Treasury, Agency, and Agency MBS collateral. Rates in the fed funds market and the repo markets decreased following the announcement. Most repo trading occurs early in the morning and was already completed by the time of the announcement. Likely for that reason, the operation was not fully subscribed.

Despite decreasing from their peak, repo rates for 1-day forward-settling trades remained elevated because market participants were not sure whether the Federal Reserve's operations would continue on subsequent days. These concerns were allayed on Tuesday afternoon when the Desk announced that it would conduct an overnight operation, at 8:15 AM, on Wednesday, September 18.²⁸

²⁸ https://www.newyorkfed.org/markets/opolicy/operating_policy_190917a

On the morning of September 20, the Desk announced a series of operations over the quarter-end, which included three 2-week operations covering the quarter-end and daily overnight operations of \$75 billion through October 10.²⁹ As a result of these operations, the supply of reserves went up, helping keep the fed funds rate into the target range.

Conditions in other money markets also improved: rates on forward-settling repo contracts spanning quarter-end and term repo contracts over quarter-end declined following the announcement. This helped reduce market participants' concerns about funding conditions over the September quarter-end. Indeed, as noted above, some dealers reduce their intermediation activity on quarter-ends because they need to report a snapshot of their regulatory ratios on those days. In addition, pressures in offshore funding markets also abated.

On October 11, 2019, the FOMC announced its intention to maintain over time an ample supply of reserves balances at or above the level that prevailed in early September.³⁰ The FOMC instructed the Desk to purchase Treasury bills at least into the second quarter of 2020, and to continue repo operations, to supply reserves and to mitigate money market pressures that might impede policy implementation. The goal of the bill purchases is to ensure the smooth functioning of money markets at the current monetary policy stance, not to change the monetary policy stance.

The Federal Reserve's interventions potentially affect several of the mechanism that generated spikes in the fed funds and repo rates. First, the increase in reserves should alleviate pressures arising from reserve scarcity. Both repo operations and outright purchases increase the level of reserves. Second, to the extent that some of the stress was related to an imbalance between the supply and the demand for cash in the repo market, both the Fed's repo operations and the outright purchases help. Repo operations increase the supply of cash in the repo market, while outright purchases reduce the supply of securities that are likely to be financed in the repo market, reducing the demand for cash.

The Federal Reserve's operations have helped maintain the supply of reserve above the level that prevailed in early September. The injection of reserves rapidly restored control of the EFFR, which has

²⁹ https://www.newyorkfed.org/markets/opolicy/operating_policy_190920. On September 25, the Desk announced that the size of overnight and term repo operations would be increase to \$100 billion and \$60 billion, respectively. The size of overnight operations returned to \$75 billion after the end of the quarter.

³⁰ <https://www.federalreserve.gov/newsevents/pressreleases/monetary20191011a.htm>

displayed little volatility over the last few month, staying well within the target range and very close to the IOER rate. Trading in other money markets has also been calm.

From the perspective of the monetary policy implementation framework, one interpretation of the mid-September events is that the EFFR, and money market rates more generally, can be unexpectedly volatile when reserves start to become scarce. This experience of the last few months suggests that a small increase in the supply of reserves, back to the level of early September 2019, was enough to restore control of the EFFR. In that sense, the FOMC's monetary policy implementation framework functions well, provided the supply of reserves is large enough.

It would be interesting to better understand the role of the supply of reserves, by itself, and the role of ongoing repo operations. Over the next few month, as the repo operations wind down, it will be possible to get a better sense of the relative importance of these two factors in maintaining smooth conditions in the fed funds market.

6. Conclusion

In this paper, we studied factors that may have contributed to the stress in US money markets in mid-September 2019. We provided an overview of the two money markets that were primarily affected, the fed funds market and the repo market, and described the links between the two markets.

Our study focused particularly on factors that were important in mid-September 2019 but had not manifested themselves before. Reserves hit their lowest level since the end of the crisis in mid-September and may have been close to or lower than the level of reserves desired by depository institutions. A low level of reserves directly explains the increase in fed funds rates, the rate at which depository institutions borrow reserves. In addition, it could help explain the increase in repo rates indirectly. Prior to mid-September some depository institutions with surplus reserves would provide cash to the repo market whenever repo rates were elevated, dampening the effect of cash imbalances in that market. It is possible that these depository institutions did not have surplus reserves to lend in mid-September.

We also show how a decrease in money market mutual funds lending through the FICC's sponsored program may have temporarily increased the intermediation cost of US GSIBs who play an important role in the repo market. This increase in intermediation cost could have led to an increase in repo rates more generally. As noted above, this factor may have interacted with reserve scarcity. Indeed, if reserves are ample, it would be possible for repo intermediaries to increase their net lending in the repo market without increasing their intermediation costs by redeploying surplus reserves from their DI affiliate.

The Federal Reserve's response to the mid-September events highlight the importance of maintaining a sufficiently large supply of reserve for the monetary policy implementation framework to operate effectively. In the last few months, with the supply of reserves above the level that prevailed in early September, trading in the fed funds market, and in other money markets, has been smooth.

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