

**Finance and Economics Discussion Series
Divisions of Research & Statistics and Monetary Affairs
Federal Reserve Board, Washington, D.C.**

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2021-028

Please cite this paper as:

Anbil, Sriya, Alyssa Anderson, and Zeynep Senyuz (2021). “Are Repo Markets Fragile? Evidence from September 2019,” Finance and Economics Discussion Series 2021-028. Washington: Board of Governors of the Federal Reserve System, <https://doi.org/10.17016/FEDS.2021.028>.

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Are Repo Markets Fragile?

Evidence from September 2019*

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April 2021

Abstract

We show that the segmented structure of the U.S. Treasury repo market, in which some participants have limited access across the segments, leads to rate dispersion, even in this essentially riskless market. Using confidential data on repo trading, we demonstrate how the rate dispersion between the centrally cleared and over-the-counter (OTC) segments of the Treasury repo market was exacerbated during the stress episode of September 2019. Our results highlight that, while segmentation can increase fragility in the repo market, the presence of strong trading relationships in the OTC segment helps mitigate it by reducing rate dispersion.

Keywords: repo market, OTC market, CCP, segmentation, financial stability

JEL Classification: G23, G10, E43, E52

*We thank David Bowman, Mark Carlson, Kevin Clark, Jim Clouse, Thomas Doherty, Chris Gust, Sebastian Infante, Adam Kirk, Josh Loria, Marco Macchiavelli, Antoine Martin, Anthony Sarver, Bernd Schlusche, Phillip Weed, and Tim Wessel. We also thank seminar participants at the Federal Reserve Board and conference participants at the CEBRA Annual Meeting, Federal Reserve System Committee on Financial Institutions, Regulation, and Markets, and Federal Reserve System Week-After Conference on Financial Markets and Institutions for helpful comments. We thank Elizabeth Getis, Luke Morgan, and Nicole Trachman for excellent research assistance. The views expressed in this paper are solely the responsibility of the authors and should not be interpreted as reflecting the views of the Federal Reserve Board, or other members of its staff. All remaining errors are our own.

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1 Introduction

The smooth functioning of the repo market is critical for both stability of the financial markets and monetary policy implementation in the United States.¹ Prior literature discusses the vulnerability of the repo market to runs during the Global Financial Crisis of 2007-08 (GFC).² One feature of the repo market that was thought to make it potentially unstable during the GFC was the lack of a widely used central clearing party (CCP). By eliminating counterparty risk and allowing for transparent trading with full access for all participants, a CCP should be able to anchor market rates and prevent a core well-connected group of traders from engaging in rent-seeking behavior with periphery traders (Duffie and Zhu (2011); Glode and Opp (2019); Loon and Zhong (2014); and Loon and Zhong (2016)). Following the passage of the Dodd-Frank Act, private initiatives pushed to expand the role of a CCP (Powell (2015); Duffie (2020)).³ However, over time, the U.S. repo market became more segmented given the persistence of an alternative over-the-counter (OTC) segment and limited access for some participants to both segments.

In this paper, we demonstrate how the benefits of a CCP may not be fully realized when an OTC segment is still present, as is the case in the U.S. Treasury repo market. While a CCP is expected to increase transparency, the segmented market structure results in rate dispersion between the two segments, even in this essentially riskless market in which borrowing is backed by the safest collateral. We find evidence that strong trading

¹The repo market is an essential source of funding for many market participants, with over \$1 trillion in overnight repo backed by Treasury collateral alone traded each day (<https://apps.newyorkfed.org/markets/autorates/SOFR>).

²See for example Copeland et al. (2014), Krishnamurthy et al. (2014), and Gorton and Metrick (2012).

³The Fixed Income Clearing Corporation (FICC) offered clearing services before the GFC. Market participants report that volumes were small but the data are unavailable to confirm these anecdotal reports.

relationships in the OTC segment help mitigate some of this rate dispersion. We investigate these trading dynamics using the money market stress episode of September 2019.

In mid-September 2019, repo rates spiked and exhibited significant volatility. Although some upward pressure on rates was expected due to the corporate tax date and Treasury coupon settlement, the extent of pressures observed caught many by surprise. The level of the Secured Overnight Funding Rate (SOFR), an aggregate median rate in the overnight Treasury repo market that includes transactions in both the OTC and CCP segments, more than doubled on September 17. We find that, during this stress episode, rate dispersion between the two segments increased by 7 standard deviations.

We analyze trading dynamics in two major segments of the U.S. Treasury repo market: (i) tri-party repo featuring OTC trading between high-credit-quality broker-dealers (dealers) and primarily money market mutual funds (MMFs), and (ii) repo centrally cleared by the Fixed Income Clearing Corporation (FICC), or FICC-cleared, where large dealers and banks lend to other dealers. In the tri-party segment, trading dynamics depend on strong relationships between dealers and MMFs, whereas in the FICC-cleared segment, with quotes displayed on Bloomberg and TradeWeb screens, the need for direct interaction between borrowers and lenders is eliminated.⁴ Although many financial institutions are eligible to participate in the FICC-cleared segment, only high-credit-quality dealers and banks are able to directly access both repo segments. Therefore, these high-credit quality dealers have the option to arbitrage between segments by borrowing from mostly MMFs in tri-party and then lending in the FICC-cleared segment.

⁴Throughout the paper, when referring to the tri-party segment, we exclude the General Collateral Finance (GCF) segment, and when referring to the FICC-cleared segment, we only refer to the FICC-cleared delivery-versus-payment (DVP) segment. See Section 2 for further details.

We demonstrate that two related dynamics help explain the increased rate dispersion between the repo segments during the stress episode of September 2019. First, smaller dealers with access to only the FICC-cleared segment borrowed more than usual at substantially higher rates. These dealers paid, on average, almost 1 percentage point higher relative to other FICC participants, given their inelastic demand and lack of access to the tri-party segment. As a result, the high-credit-quality dealers earned roughly eight times more than their average profit on September 16-17. Second, in the tri-party segment, where trading relationships between MMFs and dealers are well-established, the same high-credit-quality dealers, on average, paid nearly 3 percentage points more to borrow from their MMF lenders on those two days than on other days. These dealers intermediating between both segments passed on much of their profit from the FICC-cleared segment to their MMF counterparties. The aggregate transaction volume and the composition of trades remained quite stable in the tri-party segment despite higher rates on those two days.

Our results highlight the “repeated game” nature of trading relationships in the tri-party segment, where dealers need to maintain their reputations as reliable borrowers from MMFs, as described in Hendershott et al. (2020). We show that, on normal days, dealers with strong trading relationships passed on at least half of their profit from the FICC-cleared segment to their MMF lenders in the tri-party segment.

We also provide empirical evidence that MMFs’ bargaining power in their relationships with dealers increased following two events: (i) the publication of SOFR in April 2018, and (ii) the expansion of sponsored repo services in March 2019. After the publication of SOFR, rate dispersion between the two segments declined since this benchmark rate provided new information to MMFs about the rate at which their borrowers were lending in the FICC-cleared segment, thereby allowing MMFs to demand similar rates in the tri-party segment.

This finding is in line with Duffie et al. (2017), who show that the publication of a benchmark rate reduces profit margins and may increase the bargaining power of smaller participants with previously little visibility into the market. MMFs’ bargaining power also increased after the expansion of sponsored repo services in March 2019, which allowed them to indirectly lend in the FICC-cleared segment. The expansion allowed dealers to trade on behalf of a “sponsored client” (e.g., a MMF), thereby enabling some MMFs to lend at higher rates in the FICC-cleared segment compared to the tri-party segment. Increased competition in the FICC-cleared segment reduced profits for high-credit-quality dealers. Additionally, the bargaining power of MMFs in the tri-party segment increased as they gained access to an alternative repo segment to lend. We show that after both of these events, the rate spread between the two segments narrowed due to increased transparency and access.

Finally, we assess the role of balance sheet constraints faced by large dealers in affecting trading dynamics. While generally not binding, regulatory constraints typically affect large dealers’ internal risk management practices. Since borrowing in the tri-party segment expands the balance sheet while borrowing in the FICC-cleared segment does not given that trades are only nettable in the latter, balance sheet constraints may affect the spread required to intermediate between segments. We find that dealers with more constrained balance sheets required a larger spread to intermediate between segments compared to less constrained dealers. However, in September 2019, when the profit of intermediating between segments spiked, dealers with more constrained balance sheets acted similarly to those with less constrained balance sheets when profits were high.

Our paper contributes to the literature in three important dimensions. First, our findings on the significance of the repo market microstructure complement those of Mancini et al. (2015), who show that the presence of a CCP in the non-segmented European repo market

makes the market more resilient. Our results suggest that, with multiple segments that are not fully accessible to all participants, as in the U.S. repo market, the market may be more fragile to shocks.

Second, our results highlight the importance of trading relationships that are prevalent in the OTC segment, where borrowers and lenders must seek each other. We show that the strength of relationships significantly affects how trading dynamics play out. When relationships do not exist because borrowers and lenders submit trade parameters blindly, as in the FICC-cleared segment, lenders may earn higher rates given inelastic borrowing demand. However, when relationships matter as they do in the tri-party segment, dealers may not be able to fully take advantage of arbitrage opportunities without threatening their relationships with MMFs, leading them to pass on some of their arbitrage profit to their lenders in tri-party, thereby reducing rate dispersion between segments. Our results complement those by Maggio et al. (2017), who find that dealers change their behavior based on the strength of their trading relationships, and by Maggio et al. (2019), who find that “clients” can make more money from their dealer counterparties due to the information revealed through trading relationships. Our result that relationship dynamics persist in the tri-party segment even in the face of extreme market stress is also consistent with those of Anderson and Kandrak (2018), Anbil and Mojir (2020), and Anbil and Senyuz (2018).

Third, we contribute to the understanding of repo market dynamics during stress episodes. Our results shed light on how the repo market behaved during the GFC, as discussed by Krishnamurthy et al. (2014) and Copeland et al. (2014). Further, Infante (2019) and Martin et al. (2014) show how collateral and liquidity constraints contributed to different run dynamics in this market. We provide evidence that a segmented market structure may also increase the fragility of the repo market, even when liquidity is abundant and the collateral is

super-safe. Furthermore, our analysis sheds light on how these dynamics played out during the stress episode of September 2019. The factors behind the unusual rate spikes in September 2019 are summarized in Anbil et al. (2020), Afonso et al. (2020), and Schulhofer-Wohl (2019). We build on this discussion by showing how the segmented structure of the repo market may have amplified the pressures observed at that time. These frictions also came to light during the COVID-19-related market turbulence in March 2020.

The rest of the paper proceeds as follows. Section 2 provides background information on the structure of the repo market. Section 3 provides estimates of the normal effects of seasonal factors on repo rates compared to what was seen in mid-September 2019. Section 4 describes the confidential data sets, and the construction of control variables. Section 5 lays out the empirical framework and presents the results. Section 6 provides intuition for the results and discusses the underlying factors. Section 7 concludes.

2 Background: The Repo Market

The repo market is a crucial source of short-term funding for many financial institutions that use repo to finance the securities held on their balance sheets. In this section, we provide some background information on repo transactions and the structure of the market.

2.1 What is Repo?

A repo transaction is a short-term secured loan that involves the sale and future repurchase of a security between a borrower and lender. The cash borrower owns the security and seeks cash (repo), while the cash lender receives the security as collateral when lending the cash (reverse repo). On the maturity date, the borrower returns the cash with interest to

the lender and the collateral is returned to the borrower. In this paper, we focus on the Treasury repo market since it is the largest, safest, and most liquid type of repo. Although the exact size of the overall Treasury repo market is unknown, more than \$2 trillion dollars of cash and securities change hands in the Treasury repo market everyday (Baklanova et al., 2019).

2.2 Repo Market Segments

The Treasury repo market consists of four segments. Figure 1 shows average daily volumes for overnight repo over 2019 in these four segments. Daily overnight Treasury repo volumes in the FICC-cleared segment averaged around \$700 billion a day (orange), while volumes in the tri-party segment averaged around \$450 billion a day (blue). General Collateral Finance (GCF) is a small, mainly interdealer platform and provides funding for dealers that may not have sustainable access to cash in other segments of the repo market. It accounts for a very small portion of overnight Treasury repo activity, about \$50 billion per day (yellow). Overall, these three segments roughly make up the components of the SOFR.⁵ The remaining portion shown in gray is the uncleared bilateral segment, in which parties conduct trades directly with each other. Although the size of the uncleared segment is unknown due to data limitations, Baklanova et al. (2019) estimate that the total volume across all collateral types was above \$3 trillion in early 2015.

While other collateral types are traded in all segments, Treasury-backed repo is the largest, safest, and most liquid. Furthermore, repo backed by Treasuries is primarily overnight, contributing to its safety.

⁵The SOFR calculation excludes all transactions with rates below the 25th volume-weighted percentile rate in the FICC-cleared segment each day. This has the effect of removing some (but not necessarily all) transactions in which the collateral are said to be trading “special”; that is, the specific collateral is in high demand so the rate on the repo transaction is low.

In this paper, we focus on the two main segments of the Treasury repo market: the FICC-cleared repo segment and the tri-party repo segment. When we refer to the FICC-cleared segment, we refer to the FICC delivery-versus-payment (DVP) segment, in which the vast majority of trades are blind-brokered between borrower and lender. When we refer to the tri-party segment, we exclude the GCF segment. Despite being cleared on the tri-party platform, it is a segment with very different participants and dynamics than the rest of the tri-party segment.

In the FICC-cleared segment, net lenders include larger dealers and banks while net borrowers include smaller dealers. To trade in the FICC-cleared market, an entity must be a FICC member and meet certain criteria. Lenders and borrowers do not interact directly to agree on the terms and settle the trade, but instead typically use a broker and then face the central clearing party, FICC. The blue flow chart of Figure 2 shows how trading terms are negotiated in the FICC-cleared segment. Borrowers and lenders view brokers' transparent rate screens on Bloomberg or TradeWeb and submit the conditions at which they are willing to trade blindly to a broker. The broker receives these conditions, matches them, and novates the trade to FICC. FICC receives these conditions and nets out the transactions for each participant. All borrowers and lenders face FICC as their counterparty for the trade. The vast majority of the segment is considered "blind-brokered" where borrowers and lenders do not know their counterparties, meaning trading relationships do not exist in this segment.

Collateral is sent by the borrower to FICC for the course of the trade and counterparty risk is negligible. Borrowers and lenders identify specific securities to settle each trade, rather than a population of acceptable collateral. That is, for example, the borrower must pledge a specific CUSIP of Treasury, rather than a generic Treasury security. As a result, the FICC-cleared segment can be used to temporarily acquire specific securities. Finally,

FICC nets out collateral across transactions for each participant, reducing the impact of the trades on the size of the participant’s balance sheet. Many participants run a “matched book”; that is, they both borrow and lend on the same day against the same collateral. These intermediation trades are then netted. Their profit or funding costs depends on the spread between their lending and borrowing.

In the tri-party segment, lenders and borrowers use the services of Bank of New York Mellon (BNYM) as a custodian bank, which provides back office efficiencies over the course of the transaction. Lenders are primarily MMFs, but can also include asset managers, banks, Federal Home Loan Banks (FHLBs), and corporations. Borrowers are high-credit-quality dealers that include primary dealers.⁶ Figure 2 also shows how trading terms are negotiated in the tri-party repo segment. The purple flow chart highlights that trading relationships are important here because a borrower must seek a lender (or vice versa) to trade. Once terms are agreed on, collateral is sent by the borrower to BNYM for the duration of the trade. If the borrower declares bankruptcy, the lender is able to sell the collateral held at BNYM without entering the borrower’s bankruptcy process (Martin et al., 2014). As a result, counterparty risk is negligible in this segment, similar to the FICC-cleared segment. However, unlike in the FICC-cleared segment, collateral must simply meet predetermined general eligibility requirements to be accepted, rather than be a specific CUSIP. Therefore, the rate negotiated between borrower and lender is not affected by specific securities; all

⁶The majority of high-credit-quality dealers are primary dealers. Primary dealers are trading counterparties of the Federal Reserve Bank of New York (FRBNY) in its implementation of monetary policy and are expected to bid in all Treasury auctions at reasonably competitive prices. The current and historical lists of primary dealers are located at <https://www.newyorkfed.org/markets/primarydealers.html>. Financial intermediation of primary dealers can affect prices across asset classes (He et al., 2017). Primary dealers are broker-dealers and are not part of the “bank” arm of the bank holding company (BHC). Broker-dealers buy and sell securities for its own firm or on behalf of its clients and do not hold reserves. Banks, however, are a separate subsidiary of the BHC and hold deposits as liabilities and reserves as assets. Banks and broker-dealers, even within the same BHC, are considered different trading entities.

Treasury securities are treated equally. However, in this segment, collateral is not netted out across transactions and can constrain borrower’s balance sheets.

Figure 3 plots the overnight Treasury repo volume in the FICC-cleared and tri-party segments since January 1, 2018. We observe that volumes have steadily increased over time, especially in FICC-cleared repo. Further, because the participants in the tri-party repo segment are, on average, considered of higher credit quality in comparison with participants in the FICC-cleared repo segment, even though there is no counterparty risk in either segment, rates in the tri-party segment typically trade a few basis points lower than the FICC-cleared segment. Figure 4 displays the spread between segments, defined as the volume-weighted median rate of transactions in the FICC-cleared segment minus the volume-weighted median rate of transactions in the tri-party segment from January 1, 2017 to December 31, 2019. On average, rates in FICC-cleared trade about 10 basis points higher than rates in tri-party.

Finally, an important change to the market structure came in March 2019 when the SEC allowed an expansion of FICC “sponsored service.” This service allows financial institutions that are ineligible to become FICC members directly to participate in the FICC-cleared segment by trading via a sponsor, usually a dealer.⁷ In this sponsored service, lenders are typically MMFs, while borrowers are typically hedge funds. Figure 5 shows the increase in lending via sponsored repo by MMFs since 2019.

3 Repo Dynamics and September 2019

In the Treasury repo market, rate movements are expected on certain days due to “seasonal factors”. These seasonal factors include Treasury settlement dates (mid-months and month-

⁷More information about sponsored repo can be found here: <https://www.dtcc.com/clearing-services/ficc-gov/sponsored-membership>. The most recent list of institutions that participate via sponsored repo are found here: <https://www.dtcc.com/client-center/ficc-gov-directories>.

ends), corporate tax payment dates (some mid-months), and regulatory reporting dates (month-ends). On Treasury coupon settlement days, we typically see upward pressure on repo rates, given the increase in the amount of securities that need to be financed in the repo market. Similarly, on corporate tax payment dates, we observe upward pressure on repo rates because MMFs lend less as they experience outflows due to withdrawal of funds by their clients making their quarterly tax payments. Finally, on regulatory reporting dates, some dealer borrowers pull back from the repo market to reduce the size of their balance sheet for reporting their leverage ratios. Anticipating reduced demand for repo, lenders also adjust their cash lending. The upward pressure on repo rates comes from borrowers that are willing to pay up to meet liquidity shortfalls.⁸

To measure the extent of upward pressure on repo rates in response to these seasonal factors, we estimate Equation 1 using daily data from January 1, 2017 to September 13, 2019. Our dependent variable is the change in the spread between SOFR and the interest rate on excess reserves (IOER).⁹

$$\begin{aligned} \Delta(SOFR - IOER)_t = & \alpha + \beta_1 1(t = \text{midmonth})_t + \beta_2 1(t = \text{monthend})_t \\ & + \beta_3 1(t = \text{monthstart})_t + \epsilon_t \end{aligned} \tag{1}$$

We include three indicator variables for calendar days associated with the seasonal factors that affect repo rates. The effect of Treasury coupon issuance days on mid-month and month-end days are captured by β_1 and β_2 , respectively. Corporate tax payment dates also coincide

⁸See Anbil and Senyuz (2018) for a detailed analysis of how these reporting dynamics affect repo trading.

⁹The reason for considering the spread rather than the level of SOFR is to control for the changes in the stance of monetary policy, as well as technical adjustments to the administered rates, implemented over this time period.

with mid-months so their effects are captured by β_1 . The effect of reversal of month-end pressures on the first day of the next month is captured by β_3 .

Table 1 summarizes the estimation results. We find that mid-month Treasury settlement days lead to an upward pressure on the repo rate of about 6 basis points, on average, over our sample period. The upward pressure on the repo rate on month-ends is 15 basis points, on average. It typically takes a few days for the upward pressure to vanish at the beginning of the month. We find that about half of the increase in repo rates on month-ends is reversed on the next day.

As shown in Figure 6, the moves in SOFR observed on September 16 and 17 were much larger than any of those observed over the prior few years. Although some upward pressure on repo rates was expected in response to the seasonal factors just discussed, the extent of the increase in both the level and volatility of rates in the repo market took many by surprise. In particular, the results from Equation 1 show that the average effect on repo rates resulting from the settlement of Treasury coupons and corporate tax dates are typically around 6 basis points, much smaller than the actual increase observed on September 16. As shown in Figure 7, repo rates underlying the SOFR shifted higher on September 16 and 17. Following the Fed's announcement of repo operations on September 17, the distribution of rates reverted closer to normal the next day. Anbil et al. (2020), Afonso et al. (2020), and Correa et al. (2020) discuss the factors that caused the upward pressure on overnight funding rates in mid-September in much more detail.

4 Data and Summary Statistics

4.1 Repo Data

We construct two confidential data sets for overnight Treasury repo activity that takes place in the FICC-cleared segment and the tri-party segment, respectively. Our first data set includes data on overnight FICC-cleared transactions from January 1, 2017 to December 31, 2019. The daily data include the rate, volume, and CUSIP of Treasury collateral for all transactions in the segment, but not the identity of the borrower or lender. Since most of the FICC-cleared repo market is blind-brokered, that is, participants do not know their trading counterparties, trading relationships are nonexistent in this segment.

Because we cannot identify borrowers or lenders using our FICC-cleared data set, we use additional data to come up with representative rates and volumes by participant type. We first classify the list of FICC participants into three types based on their access to different repo segments: all-access, FICC+tri-party, and FICC-only.¹⁰ Together, these participant types are mutually exclusive and exhaustive. Figure 8 illustrates how each participant type can access each repo segment. First, all-access participants, which are primary dealers, are able to access the tri-party and FICC-cleared segments, and borrow at Federal Reserve repo operations (purple arrows). Second, FICC+tri-party participants are able to access both the tri-party and FICC-cleared repo segments, but are ineligible to borrow at Federal Reserve repo operations, as they are not primary dealers (green dashed arrows). Finally, FICC-only participants, which are typically small broker-dealers, can only trade in the FICC-cleared repo segment; they cannot access the tri-party segment nor participate at Federal Reserve repo operations.

¹⁰The list of participants is available on DTCC's website at <https://www.dtcc.com/client-center/ficc-gov-directories>.

We then calculate the distribution of representative borrowing and lending rates and volumes for each participant type (all-access, FICC+tri-party, and FICC-only). We apply this distribution across our entire data set from January 1, 2017 to December 31, 2019 to arrive at representative borrowing and lending rates and volumes for each participant type each day. We are able to confirm the validity of this distribution using internal confidential daily data that does provide the identities of the borrowers and lenders in the FICC-cleared segment for all days in our sample period.

Our second data set includes overnight Treasury repo transactions that take place on the BNYM platform in the tri-party repo segment, including rate, volume, borrower, and lender for each transaction.¹¹ We restrict our sample to transactions in which the lender is a MMF.¹² In particular, we identify MMFs at the fund level and aggregate them to the complex level, since investment decisions are first made at the complex level and then filtered down to individual funds, following the approach in Anbil and Mojir (2020). The final data set runs from January 1, 2017 to December 31, 2019.

4.2 Summary Statistics

Table 2 displays the number of participants in both the tri-party and FICC-cleared repo segments. There are 45 lenders in tri-party repo, which are all MMF complexes, and 29 borrowers, which are dealers, resulting in 529 unique dealer (borrower)-MMF (lender) pairs. All borrowers in the tri-party segment can participate in the FICC-cleared segment. Of the 134 participants in the FICC-cleared segment, 31 are all-access, 73 are FICC+tri-party, and

¹¹We exclude all open, or rolling, trades, which constitute about only 0.5% of transactions in this segment.

¹²MMFs are the predominant lenders in the tri-party segment and other smaller lenders are difficult to identify in the data given non-standardized lender names. Restricting to MMFs drops approximately 20% of transactions.

30 are FICC-only participants.¹³ Additionally, there are 11 sponsored members that trade on behalf of MMFs and levered investors. These 11 sponsored members are included in the FICC+tri-party category.

Dealers often intermediate in the FICC-cleared market, running a “matched book”; that is, they borrow and lend on the same day.¹⁴ To measure the return or cost of this intermediation, we define two matched book spreads. First, we define the “within-FICC spread” as the volume-weighted average lending rate minus the borrowing rate for all participant types trading in the FICC-cleared segment. FICC-only participants are typically net borrowers in this market, while all-access and FICC+tri-party participants can either be net lenders or borrowers. A positive “within-FICC spread” is the profit earned by intermediating within the FICC-cleared segment. Second, participants with access to both segments (all-access and FICC+tri-party) can intermediate between the two segments by borrowing in the tri-party segment at lower rates and lending in the FICC-cleared segment at higher rates. We define the “between-segment spread” as the volume-weighted average lending rate in FICC-cleared segment minus the volume-weighted average borrowing rate in tri-party segment. A positive “between-segment spread” reflects the profit earned by intermediating between the two repo segments. We refer to the spread as profit, but it can also be thought of as the cost of intermediation. As discussed in Section 2, collateral across transactions in the FICC-cleared segment is nettable, but in the tri-party segment it is not. Lending in FICC and borrowing in tri-party increases the size of the participant’s balance sheet. Therefore, trading across segments might be costly for large dealers who face both regulatory and internal constraints

¹³One BHC may have multiple legal entities, which increases the number of participants, e.g. four broker-dealer legal entities and one bank entity could belong to one BHC, making it appear that there are far more participants in FICC-cleared than in tri-party.

¹⁴This process is known as “rehypothecation”. The difference in trading rates implies a profit or loss for the institution. See Infante (2019) for details about the implications of rehypothecation.

on the size of their balance sheet. As a result, the “between-segment spread” may be reflective of dealers requiring compensation to intermediate these trades rather than seeking profit.

4.3 Tri-party Repo Control variables

4.3.1 Borrower and Lender Variables

We construct several control variables to establish robustness of our empirical results in our tri-party repo analysis, where we refer to borrower (dealer) i and lender (MMF complex) j on day t . Since all borrowers in the tri-party repo segment are in the all-access or FICC+tri-party participant groups, they can also earn the “between-segment spread” by borrowing in the tri-party segment at lower rates and lending in the FICC-cleared segment at higher rates. Recall that MMF lenders are unable to directly participate in FICC.

First, using the quarterly Consolidated Report of Condition and Income Reports from the Federal Financial Institutions Examination Council (FFIEC), or call reports, we construct two balance sheet measures for each dealer i at quarter q : (i) dealer’s total assets ($TotalAssets_{i,q}$) and (ii) dealer’s short-term funding dependence ($STFD_{i,q}$), calculated as follows:¹⁵

$$STFD_{i,q} = \frac{(ST\ Noncore\ Funding)_{i,q} - (ST\ Investments)_{i,q}}{(LT\ Assets)_{i,q}} \quad (2)$$

¹⁵STFD was developed by bank supervisors as a measure of banks’ short-term funding dependence. For specific definitions of the numerator and denominator, see pages 3-6 of <https://www.federalreserve.gov/boarddocs/supmanual/bhcpr/UsersGuide13/0313.pdf>. Total assets is item RCFD2170 on FFIEC 002 or FFIEC 031; or item RCON2170 on FFIEC 041 or FFIEC 051. Of the 29 borrowers in the tri-party repo segment, 5 borrowers do not have commercial bank entities in the US and therefore do not need to report regulatory ratios to the FFIEC.

We control for market share of each borrower to account for the possibility of borrowers with larger market share getting more favorable rates from their counterparties. We calculate a dealer’s market share as follows:

$$(\text{Market Share})_{i,t} = \frac{(\text{Repo Vol})_{i,t}}{(\text{Total Repo Vol})_t} \quad (3)$$

To construct control variables for the lenders (MMF complexes), we use the SEC N-MFP filings to calculate MMF complex total assets under management (AUM), Treasury repo investments, and the amount of Treasury securities held. N-MFP filings are filed monthly by each MMF fund. Since we aggregate the data to the MMF complex level, and many funds are part of a complex, we also aggregate the N-MFP filings to the complex level. These control variables capture MMF complexes’ dependence on lending in repo markets and their preference for lending in the Treasury repo market versus buying Treasury securities outright, which are close substitutes.

4.3.2 Borrower-Lender (Relationship) Variables

Finally, we include several variables to capture the strength of the relationship of each borrower-lender (i, j) pair, in light of the evidence that trading relationships affect rates and volumes in this segment (see, for example, Anbil and Senyuz (2018) and Anderson and Kandrach (2018)).

First, we define *Days In Relationship* as the number of days a borrower-lender pair has traded on a given day. A pair is considered “in a relationship” if the borrower-lender pair

traded at least once every two days. If the borrower-lender pair fails to trade at least once every two days, then this variable restarts at 0.¹⁶

Second, to capture the importance of the borrower (lender) to the lender’s (borrower’s) business, we define two daily variables for each borrower-lender i, j pair. The borrower’s (lender’s) share of the lender’s (borrower’s) business is defined as follows:

$$(\textit{Share of Business})_{i(j),j(i),t} = \frac{(\textit{Repo Vol})_{i,j,t}}{(\textit{Repo Vol})_{i(j),t}} \quad (4)$$

Since the share of business for the borrower and lender are contemporaneous, we also create rolling averages of *Share of Business* for borrower and lender, respectively, from day $t - 11$ to day $t - 1$. *Rolling Share of Business* captures the history of the share of business for each borrower-lender pair.

Third, to capture dynamics of borrower-lender pairs that trade more frequently than other pairs, we define *Number of Days Since Last Trade* for each pair.

Fourth, *Frequency of Trading* captures the frequency of trading between a borrower and lender on day t . It is defined as a ratio of number of transactions between lender j and borrower i on day t to total number of transactions by each party on the same day. We also define *Rolling Frequency of Trading* to capture the frequency of trading history from $t - 11$ to $t - 1$.

¹⁶We are able to identify the start of all the relationships in our data set because we define *Days In Relationship* based on transaction data from the tri-party repo segment since August 2012. See Anbil and Mojir (2020) for a discussion of the robustness of this measure.

5 Repo Trading Activity in September 2019

5.1 FICC-Cleared Segment

To analyze the behavior of each participant type in the FICC-cleared segment during the mid-September episode, we estimate the following daily panel regression from January 1, 2017 to December 31, 2019:

$$\begin{aligned} WithinFICCSpr_{p,t} = & \beta_0 + \beta_j \sum_{j=1}^4 WithinFICCSpr_{p,t-j} \\ & + \theta_1 1(p = all - access)_p \times 1(t = Sep.16 - 17)_t \\ & + \theta_2 1(p = FICC + triparty)_p \times 1(t = Sep.16 - 17)_t \\ & + \delta_{1p,t} + \alpha_p + \phi_t + \epsilon_{p,t} \end{aligned} \quad (5)$$

where $WithinFICCSpr_{p,t}$ denotes the within-FICC spread; that is, the difference between the volume-weighted average lending rate minus the borrowing rate paid by participant type p (all-access, FICC+tri-party, or FICC-only) on day t . We use two indicator variables to label the participant type: $1(p = all - access)$ equals 1 for the all-access participant type, and $1(p = FICC + triparty)$ equals 1 for the FICC+tri-party participant type. Another indicator variable is used to label September 16 and 17, 2019, when strains in the repo market were observed; that is, $1(t = Sep.16 - 17)$ equals 1 on those dates. Significant positive estimates for θ_i for $i = 1, 2$ would indicate an increase in the within-FICC spread for a participant type on these days relative to the FICC-only participant type, which is the omitted group. $\delta_{1p,t}$ includes participant type p 's net volume defined as the volume borrowed minus the volume lent by participant type p on day t . We include participant type

fixed effects (α_p) and daily time fixed effects (ϕ_t).¹⁷ We also include up to four lags of the within-FICC spread to account for autocorrelation, and calculate robust standard errors.

Additionally, we estimate Equation 5 using either the borrowing or lending volume by participant type p on day t as the dependent variable. As shown in Table 3, all else equal, all-access participants borrowed, on average, nearly 11 percentage points or \$13 billion less (Column 1) while earning a profit of 98 basis points (Columns 3) in comparison to FICC-only participants. FICC+tri-party participants also earned a profit of 96 basis points (Column 3) in comparison to FICC-only participants. Despite the large increase in profit, these dealers did not step in to lend more, potentially because of internal constraints that restrict the total size of their balance sheet and make them less agile in responding to rate moves.

We find that FICC-only participants had to pay up almost 1 percentage point for repo on Sept. 16-17 to meet their funding needs, and borrowed a total of \$13 billion more than other participant types.¹⁸ All-access and FICC+tri-party participants saw an increase in their within-FICC spreads on these days. The market segmentation allowed all-access and FICC+tri-party participants to take advantage of higher rates in the FICC-cleared segment, whereas FICC-only participants had no alternative sources to seek financing.

5.2 Tri-party Segment

Next, we turn to the analysis of trading activity in the tri-party segment in mid-September. We estimate the following daily panel regression using data from January 1, 2017 to December 31, 2019, for borrower i on day t :

¹⁷We do not include the September 16-17 time indicator variable separately since the coefficient would not be identified given time fixed effects.

¹⁸As discussed in Section 3, in mid-September 2019, lower supply of repo financing from MMFs due to outflows for the corporate tax due date, and higher demand from borrowers to accommodate high Treasury issuance led to a supply-demand mismatch in the repo market.

$$\begin{aligned}
TriSpread_{i,t} = & \beta_0 + \beta_1 TriSpread_{i,t-1} + \beta_2 Volume_{i,t} + \theta_1 1(t = Sep.16 - 17) \\
& + \alpha_i + \phi_t + \delta_{i,t-1} + \epsilon_{i,t}
\end{aligned} \tag{6}$$

where $TriSpread_{i,t}$ is defined as the volume-weighted average rate paid by borrower i minus IOER on day t . $1(t = Sep.16 - 17)$ equals 1 if t is either September 16 or 17, 2019, and 0 otherwise. Significant positive estimates for θ_1 would indicate an increase in the spread on September 16-17, in percentage points. We include borrower fixed effects (α_i) and daily time fixed effects (ϕ_t). $\delta_{i,t-1}$ includes the borrower control variables defined in Section 4.3, namely, last quarter's $STFD_{i,q-1}$, last quarter's $TotalAssets_{i,q-1}$, and contemporaneous $MarketShare_{i,t}$. First lag of the spread is included to account for autocorrelation. Standard errors are clustered at the borrower level, as transactions are correlated over time.

Table 4 summarizes the results of this estimation. As shown in Column 2, on average, borrowers (dealers) paid 2.8 percentage points higher on September 16-17, 2019 in comparison with the average rate they paid over the period from January 1, 2017 to September 13, 2019. While these dealers had access to the FICC-cleared segment and were able to lend there at higher rates, as shown in section 5.1, they also paid up for funding in the tri-party repo segment.

Despite the increase in rates, aggregate volumes in the tri-party repo segment remained stable. Figures 9 and 10 show the transacted volumes and the associated rates by borrowers (dealers) and lenders (MMF complexes), respectively, on September 16 (blue dots) and on September 17 (red triangles), as well as 2019 year-to-date averages (green squares). As shown in these figures, transacted volumes for each individual institution were very similar on September 16 and 17 to those on normal days, even when rates were higher.

While dealers borrowed the same total amount, we next consider whether they borrowed the same amounts from the same lenders. To answer this, we estimate the following daily panel regression over the period from January 1, 2017 to December 31, 2019 between borrower (dealer) i and lender (MMF complex) j on day t :

$$\begin{aligned} TriVolume_{i,j,t} = & \beta_0 + \beta_1 TriVolume_{ij,t-1} + \theta_{1i} Borrower_i \times 1(t = Sep.16 - 17)_t \\ & + \theta_{2j} + \theta_{3i,j} + \phi_t + \delta_{1i,t-1} + \delta_{2j,t-1} + \delta_{3i,j,t} + \epsilon_{i,j,t} \end{aligned} \quad (7)$$

where $TriVolume_{i,j,t}$ is the log of dollar volume traded between borrower i and lender j on day t . If the coefficients θ_{1i} , which capture individual dealers' borrowing behavior on Sept. 16-17, are insignificant, this would suggest no change in dealers' borrowing patterns on those days, all else equal. We include lender fixed effects (θ_{2j}), borrower-lender fixed effects ($\theta_{3i,j}$), and daily time fixed effects (ϕ_t). Our borrower-, lender-, and relationship-level controls are reflected by $\delta_{1i,t-1}$, $\delta_{2j,t-1}$, and $\delta_{3i,j,t}$, respectively, as defined in Section 4.3. Standard errors are clustered at the borrower-lender level.¹⁹

Table 5 summarizes the estimation results of Equation 7 where θ_{1i} coefficients for only a random group of 11 (of 29) dealers are shown, for brevity. Column 2 shows the results when control variables are included. We observe that borrowers continued to borrow similar volumes from their same lenders on September 16-17 in comparison with other days. Moreover, the distribution of borrowing volumes did not change on those two days, as indicated by the statistically insignificant coefficients on the interaction terms. These results highlight the inelasticity of borrower (dealer) demand and suggest that dealers are heavily reliant on their trading relationships in the tri-party repo segment, and value their stability.

¹⁹Clustering at the borrower level may be too conservative relative to clustering at the borrower-lender level given the small number of borrowers. See Abadie et al. (2017) for a broader discussion.

Putting together the results from the FICC-cleared and tri-party segments of the repo market, we show that borrowing demand in both segments was inelastic, as overnight funding is hard to replace on short notice. September 2019 was no exception to this dynamic with trading volumes remained quite stable across both segments. Similar dynamics were observed during the March 2020 COVID-19-related market panic, when SOFR increased from 26 to 54 basis points even as Fed repo operations were providing daily liquidity into the repo market. The FICC/tri-party spread increased by 15 basis points, as smaller dealers with no access to the tri-party segment had to pay up to obtain funding, while large dealers with access to both segments were able to lend at higher rates in the FICC-cleared segment, earning higher profit than normal.

In both of these stress episodes, dealers paid up for funding from their MMF lenders in tri-party. The fact that much of dealers' profit from the FICC-cleared segment was passed on to their MMF lenders shows how trading relationships in the tri-party segment can influence rates. In the next section, we further investigate the motives for dealers to pay up for funding from their MMF lenders in the tri-party segment.

6 Factors Affecting Repo Trading Dynamics

In this section, we look at the factors that affect trading dynamics in the repo market. Specifically, we look into the role of MMF bargaining power in dealer-MMF relationships in the tri-party segment, and the regulatory constraints that large dealers face on the size of their balance sheets.

6.1 MMFs' Bargaining Power

We showed in Section 5.2 that dealers in the tri-party segment borrow essentially the same volumes from the same lenders every day, even when there are huge rate spikes, as in mid-September 2019. Our results highlight the importance and stability of trading relationships in the tri-party segment. The partial pass-through of the profit dealers raise in the FICC-cleared segment to MMFs in the tri-party segment suggests that MMFs have significant bargaining power in their transactions with dealers. We now examine whether the bargaining power of MMFs forced these dealers to pay up for funding over time.

First, we show that MMF bargaining power in the tri-party repo segment increased after the FRBNY began publishing SOFR daily on April 2, 2018. As described in Section 2, transactions in the FICC-cleared, tri-party, and GCF segments make up the trades underlying SOFR.²⁰ Prior to April 2, 2018, visibility into rates in the FICC-cleared segment was very limited compared to the tri-party and GCF segments, which were already more transparent due to two publicly available rates: BNYM's tri-party repo rate and the Depository Trust Clearing Corporation's (DTCC) GCF repo rate. However, only participants who had access to all three segments had complete information about rates. With the publication of SOFR, MMF lenders in tri-party gained information about FICC-cleared rates, while FICC-only participants gained more visibility into tri-party rates. We hypothesize that the publication of SOFR decreased rate dispersion between the two larger segments by increasing transparency in the repo market (Duffie et al., 2017).

Second, we provide evidence that MMF bargaining power in the tri-party segment increased after the expansion of the sponsored repo service by the SEC in March 2019. As

²⁰FRBNY also began publishing the Tri-Party General Collateral Rate (TGCR), which includes just tri-party trades, and the Broad General Collateral Rate (BGCR), which includes tri-party and GCF trades, at the same time.

mentioned in Section 2, the sponsored repo service allows non-FICC members, such as MMFs, to participate in the FICC-cleared segment through a sponsor. Indeed, as shown in Figure 5, daily sponsored lending activity by MMFs increased by over \$100 billion after March 2019. We hypothesize that the expansion of sponsored repo reduced rate dispersion across segments by providing a new outlet to tri-party lenders that were previously not allowed to lend in FICC-cleared repo.

To test these hypotheses, we first regress the 30-day rolling standard deviation of the FICC/tri-party spread, $\sigma(Spread)_t$, shown in Figure 4, on indicator variables labeling the dates of SOFR publication, sponsored repo expansion, as well as the calendar days for intra-monthly dynamics, as described in Section 3. Recall that the FICC/tri-party spread is defined as the volume-weighted average transaction rate in the FICC-cleared (DVP) segment minus the tri-party segment.

$$\begin{aligned} \sigma(Spread)_t = & \alpha + \beta_1 1(t = midmonth)_t + \beta_2 1(t = monthend)_t \\ & + \beta_3 1(t = monthstart)_t + \beta_4 1(t = SOFR\ Publication)_t \\ & + \beta_5 1(t = Sponsored\ Repo\ Expansion)_t + \epsilon_t \end{aligned} \quad (8)$$

As shown in Table 6, the standard deviation of the FICC/tri-party spread declined by 2.7 basis points after the SOFR publication, and by a further 1.7 basis points after the expansion of sponsored repo, suggesting that higher transparency and increased access reduced rate dispersion between the segments.²¹ One caveat for this result is the potential correlation between SOFR publication and other market dynamics that could affect the volatility of

²¹The two indicator variables labeling SOFR publication and sponsored repo expansion are mutually exclusive.

the FICC/tri-party spread. To alleviate this concern, in Appendix Table A.1, we include robustness analysis using the rate spread between the tri-party segment and the smaller GCF segment (GCF/BNYM spread), which has been publicly available since at least 2010. If there was no new information in the SOFR rate, we would expect no change in the volatility of the GCF-BNYM spread. However, we find that the standard deviation of the GCF-BNYM spread increased by 2.3 basis points after SOFR publication, consistent with the evidence of SOFR providing increased transparency into the FICC-cleared segment.

If MMFs' bargaining power has increased after the publication of SOFR and the expansion of sponsored repo, we would expect MMFs to force dealers with whom they have strong trading relationships to pay higher rates in the tri-party segment. This, in turn, would indicate that those dealers would have limited arbitrage opportunities to intermediate between the FICC-cleared and tri-party segments. To test this hypothesis, we estimate a panel regression from January 1, 2017 to September 13, 2019 for dealer (borrower) i that belongs to participant type p and MMF complex (lender) j on day t .²²

$$\begin{aligned}
BtwSegSpr_{p,i,j,t} = & \beta_0 + \theta_{1i,j} (Rel\ Strength)_{i,j,t} \times 1(t = SOFR\ Publication)_t \\
& + \theta_{2i,j} (Rel\ Strength)_{i,j,t} \times 1(t = Sponsored\ Repo\ Expansion)_t \quad (9) \\
& + \theta_{3i,j} (Rel\ Strength)_{i,j,t} + \beta_{2i,j} + \phi_t + \delta_{1i,t-1} + \delta_{2j,t-1} + \delta_{3i,j,t} + \epsilon_{i,j,t}
\end{aligned}$$

where $BtwSegSpr_{p,i,j,t}$ is the between-segment spread; that is, the volume-weighted average lending rate in FICC-cleared by participant type p minus the borrowing rate in tri-party by dealer i from MMF j on day t , where p is the participant type to which dealer i belongs. A

²²We end the regression before the September 16-17 repo shock given the effects of Fed repo operations on September 17 on trading dynamics in the tri-party segment, as shown in Anbil and Mojir (2020).

positive spread indicates that dealer i earned a profit by trading in both segments on day t . *Rel Strength* is a vector that captures all the relationship-level control variables defined in Section 4.3. We are particularly interested in the effects of the dealer’s (borrower) share of the MMF’s (lender) business, the MMF’s share of the dealer’s business, and the length of the trading relationship in days on trading rates, as they capture the market share and recency of a given trading relationship. Negative coefficients in $\theta_{3i,j}$ would suggest that dealers with strong relationships with their lenders have lower intermediation profits. Negative $\theta_{1i,j}$ and $\theta_{2i,j}$ coefficients would suggest that MMFs were able to demand higher rates from the dealers with whom they have strong relationships, after the publication of SOFR and the expansion of sponsored repo, respectively, as their bargaining power increased. We include borrower-lender fixed effects, $\beta_{2i,j}$, and daily time fixed effects ϕ_t . The borrower and lender control variables, as defined in Section 4.3, are denoted by $\delta_{1i,t-1}$ and $\delta_{2j,t-1}$, respectively.

Table 7 shows the estimation results. When relationships were stronger, MMFs were able to demand higher rates, on average, resulting in lower intermediation profit for dealers. This profit declines further as MMF bargaining power increases. Specifically, after the publication of SOFR, a one-standard-deviation increase in the borrower’s (dealer) share of the lender’s (MMF) business is associated with a further 0.76 basis point reduction in the between-segment spread for a total 1.42 basis point decline. Similarly, a one-standard deviation increase in the lender’s share of the borrower’s business and the number of days in the relationship are associated with 0.16 and 0.05 basis point reductions in profit following the SOFR publication. After the expansion of sponsored repo, dealers’ between-segment spread further declined by 0.98, 0.18, and 0.06 basis points, respectively, when borrowing from MMFs with whom they had strong trading relationships. Given that the average between-

market spread for a borrower is 4 basis points (not shown), the magnitude of the increase in MMF bargaining power is considerable.

Overall, these results show that increased transparency provided by the publication of SOFR and increased access through the expansion of sponsored repo reduced rate dispersion between repo segments, by increasing the bargaining power of MMFs in the tri-party segment. The intermediation profit of dealers operating in both segments declines as MMFs with whom they have strong relationships gain more bargaining power and therefore were able to demand higher rates in tri-party.

6.2 Dealers' Balance Sheet Constraints

Large dealers that have access to both tri-party and FICC-cleared segments are subject to certain regulatory requirements that may affect their balance sheet management, and hence their activity in these two segments. These regulatory requirements, including the supplementary leverage ratio (SLR) and liquidity coverage ratio (LCR), are rarely binding but may affect dealers' trading activity in the repo market through their internal risk management practices. Depending on their specific business model, dealers may be more or less willing to expand their balance sheet to exploit profit opportunities in the repo market. As discussed in Section 2, FICC provides netting benefits for its participants, but the tri-party platform does not. As a result, borrowing in tri-party and lending in FICC-cleared increases the size of a dealer's balance sheet.

We now examine the effects of the balance sheet constraints that dealers face on their intermediation activity between the FICC and tri-party segments. We split our all-access dealers into two groups – constrained and unconstrained – based on their participation at Fed repo operations that started on September 17, 2019 to alleviate the strains that emerged

in the repo market.²³ These repo operations allowed primary dealers to directly borrow from the Fed rather than the private market against high-quality collateral. Since these operations are conducted on the tri-party platform, trades cannot be netted, and therefore they expand dealers' balance sheets. Of our 29 dealer borrowers in the tri-party segment, 21 are eligible to participate at Fed repo operations (all-access dealers). If a dealer in this group chose to participate at a Fed repo operation between September 17 and October 11, 2019, we consider that dealer to be unconstrained, in terms of its balance sheet capacity. Using this classification, we identify 18 out of 21 dealers as unconstrained.

We hypothesize that unconstrained dealers will pass on more of their FICC-cleared profit to their MMF lenders given the importance of these relationships, while constrained dealers will need to earn a higher spread to intermediate between the two segments. That is, unconstrained dealers will have lower between-segment spreads than constrained dealers, even as MMF bargaining power increases. To test this hypothesis, we estimate a similar panel regression to Equation 9 from January 1, 2017 to September 13, 2019, for dealer (borrower) i that belongs to participant type p and MMF complex (lender) j on day t :

$$\begin{aligned}
BtwSegSpr_{p,i,j,t} = & \beta_0 + \theta_1 (Unconstrained Dealer)_{i,t} \times 1(t = SOFR Publication)_t \\
& + \theta_2 (Unconstrained Dealer)_{i,t} \times 1(t = Sponsored Repo Expansion)_t \\
& + \beta_{2i,j} + \phi_t + \delta_{1i,t-1} + \delta_{2j,t-1} + \delta_{3i,j,t} + \epsilon_{i,j,t}
\end{aligned}
\tag{10}$$

²³While FICC+triparty dealers may face balance sheet constraints as well, we only use all-access dealers since our identification relies on a dealer's ability to access Fed repo operations.

where $BtwSegSpr_{p,i,j,t}$ is the between-segment spread; that is, the volume-weighted average lending rate in FICC-cleared by participant type p minus the volume-weighted average borrowing rate in tri-party by dealer i from MMF j on day t , where p is the participant type to which dealer i belongs. *Unconstrained Dealer* is a dummy variable that equals 1 if the dealer participated in Fed repo operations any time between September 17 and October 11, 2019. Negative θ_1 and θ_2 coefficients would suggest that unconstrained dealers were willing to pass on more profit to their MMF lenders (lower between-segment spread) after the publication of SOFR and the expansion of sponsored repo, respectively, as MMF bargaining power increased. We include borrower-lender fixed effects, $\beta_{2i,j}$, and daily time fixed effects ϕ_t . The borrower and lender control variables, as defined in Section 4.3, are denoted by $\delta_{1i,t-1}$ and $\delta_{2j,t-1}$, respectively.

Table 8 displays the results for Equation 10. From Column (2), we observe that unconstrained dealers reduced their between-segment spread by 0.17 and 0.18 basis points, respectively, after SOFR went public and the expansion of sponsored repo. These results are consistent with unconstrained dealers being willing to pass on more of their between-segment spread to their MMF lenders in comparison with constrained dealers. That is, unconstrained dealers can accommodate their relationships with their MMF lenders more than constrained dealers can. These results suggest that, during normal days, balance sheet constraints play less of a role than relationships in determining the between-segment spread.

Having assessed the role of balance sheet constraints on normal days, we next turn to the behavior of unconstrained dealers during the mid-September 2019 episode by running a panel regression similar to that shown in Equation 10. On these two days when profit opportunities in the repo market were very high, if constrained and unconstrained dealers behaved similarly,

this provides evidence that dealer balance sheet constraints played a minimal role in dealers' decisions to intermediate between segments and the rates they charged.

Table 9 displays the results examining unconstrained dealer behavior on September 16-17. From Column (2), we observe no difference in the between-segment spread for unconstrained dealers in comparison to constrained dealers. This result suggests that all dealers acted similarly on September 16-17, and balance sheet constraints did not mitigate dealer behavior when profit opportunities are large enough.

Taken together, the results of Tables 8 and 9 provide evidence that balance sheet constraints generally play less of a role than relationships in determining the between-segment spread, although they do matter for some dealers. However, when profit opportunities are high enough, such as in mid-September, even dealers that are more constrained by the size of their balance sheet (constrained dealers) behaved similarly to unconstrained dealers.

7 Conclusion

We present evidence of frictions in the U.S. Treasury repo market that potentially reduce its resilience. We demonstrate that the benefits of having a CCP may not be fully realized when an alternative OTC segment is present, even in an essentially riskless market. Using the repo market stress episode in September 2019, we provide evidence of rate dispersion between the centrally-cleared and the OTC segments of the repo market, which amplified pressures observed during that time. Similar dynamics were observed during the March 2020 COVID-19-related market stress, when SOFR spiked for a couple days. The stress observed during that time, even as the Fed's daily repo operations were providing abundant liquidity,

again demonstrates how the segmented structure of the repo market can contribute to its fragility.

Our findings also highlight the role of strong trading relationships in the OTC segment, which can mitigate rate dispersion between segments. We find that increased transparency after the publication of SOFR as a benchmark repo rate and increased market access with the expansion of the sponsored repo service increased MMFs' bargaining power, thereby reducing rate dispersion between the segments. Finally, we find that the constraints that large dealers face on their balance sheets may affect their between-segment spreads, but when profits are sufficiently high, as they were in September 2019, these constraints have minimal effect on dealers' activity.

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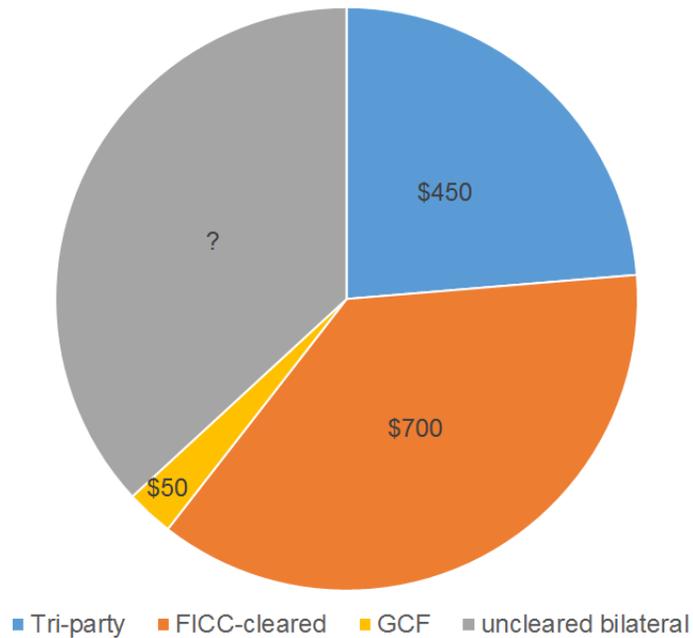
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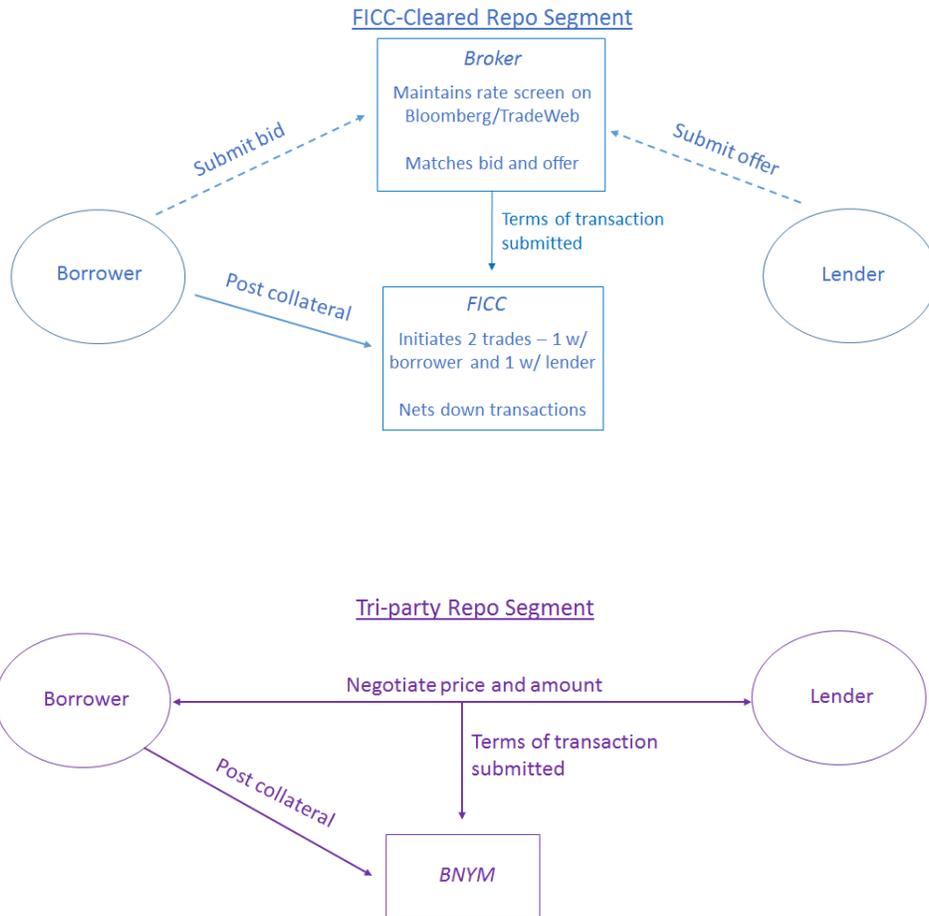
Figures and Tables

Figure 1: The Overnight Treasury Repo Market



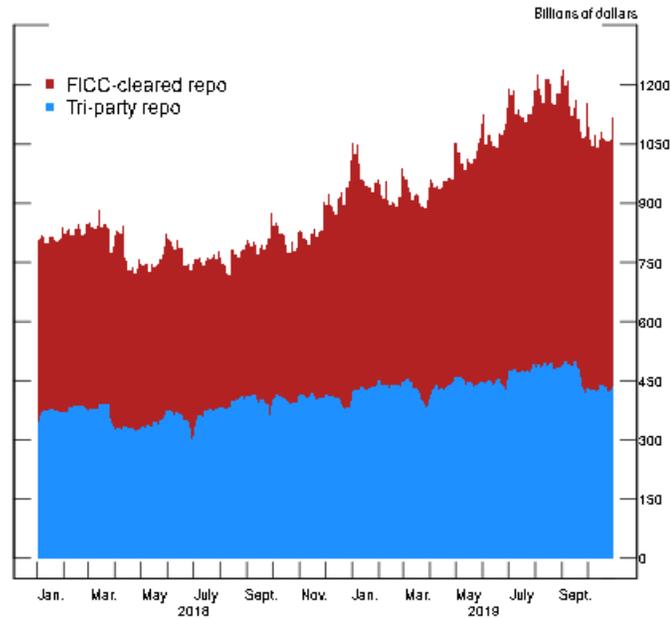
This figure illustrates the size of the overnight Treasury repo market segments: tri-party, FICC-cleared, GCF, and uncleared bilateral. The portion reflected by “?” indicates that the size of the uncleared bilateral segment is unknown. Numbers shown are daily average volumes in billions over 2019. Source: The data are from the Federal Reserve Bank of New York and are publicly available at <https://apps.newyorkfed.org/markets/autorates/SOFR>.

Figure 2: How Trade Terms are Negotiated



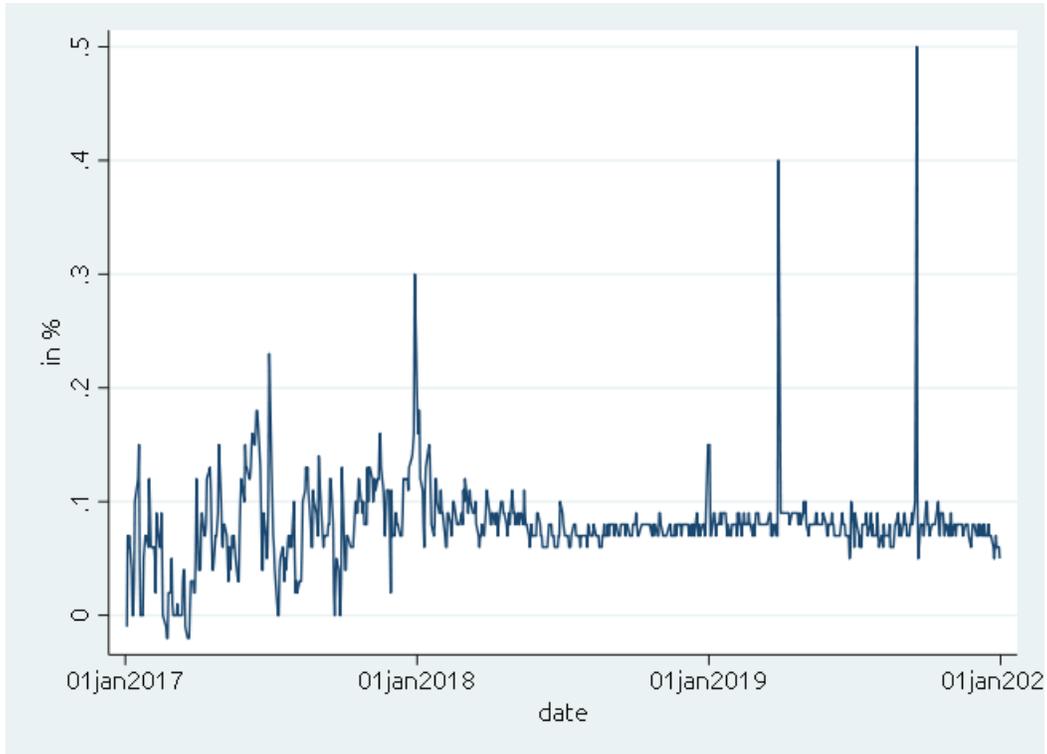
This figure shows how repo trades are negotiated in the FICC-cleared and tri-party repo segments. In FICC-cleared, the vast majority of trades are blind-brokered, and borrowers and lenders face FICC, not each other. In tri-party, borrowers and lenders must seek each other out and negotiate a trade before submitting the terms to BNYM for execution.

Figure 3: Overnight Treasury Repo Volumes



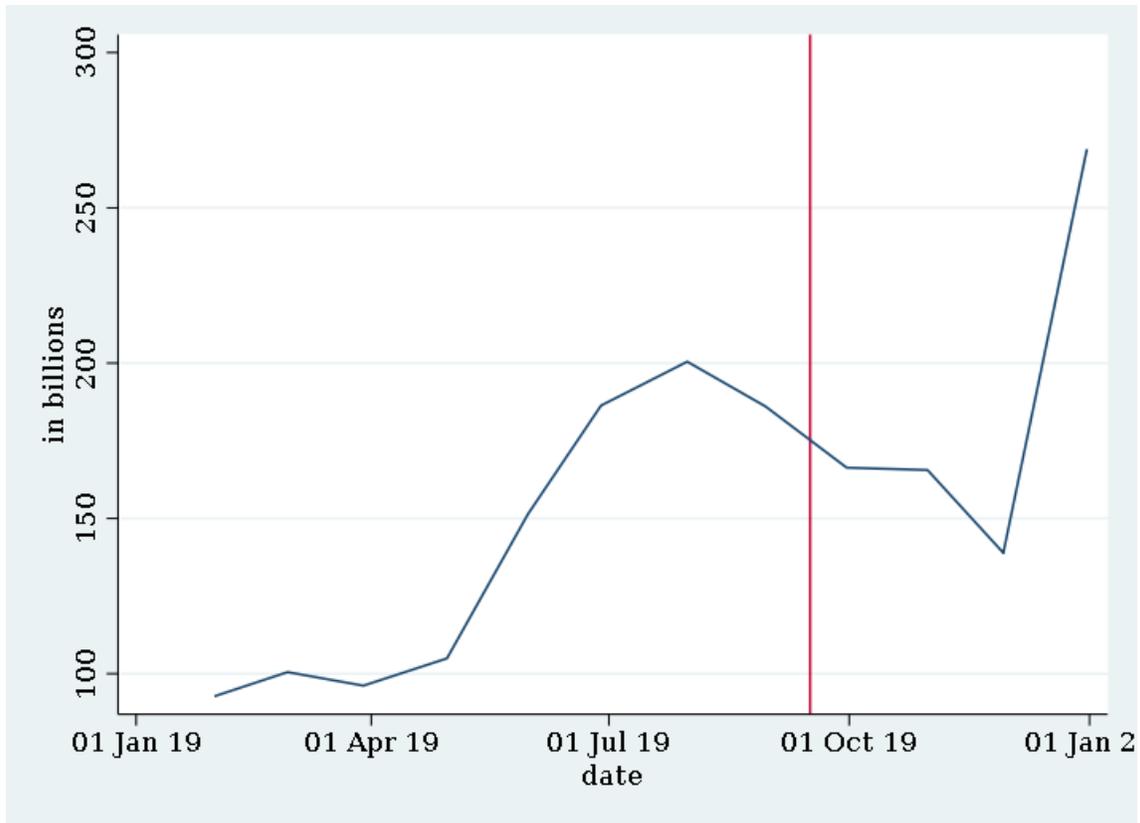
This figure displays daily overnight Treasury repo volumes in billions of dollars for the tri-party and FICC-cleared repo segments, respectively, between January 1, 2018 and November 1, 2019. Source: The data are from the Federal Reserve Bank of New York and are available at <https://apps.newyorkfed.org/markets/autorates/SOFR>.

Figure 4: FICC-Tri-party Spread



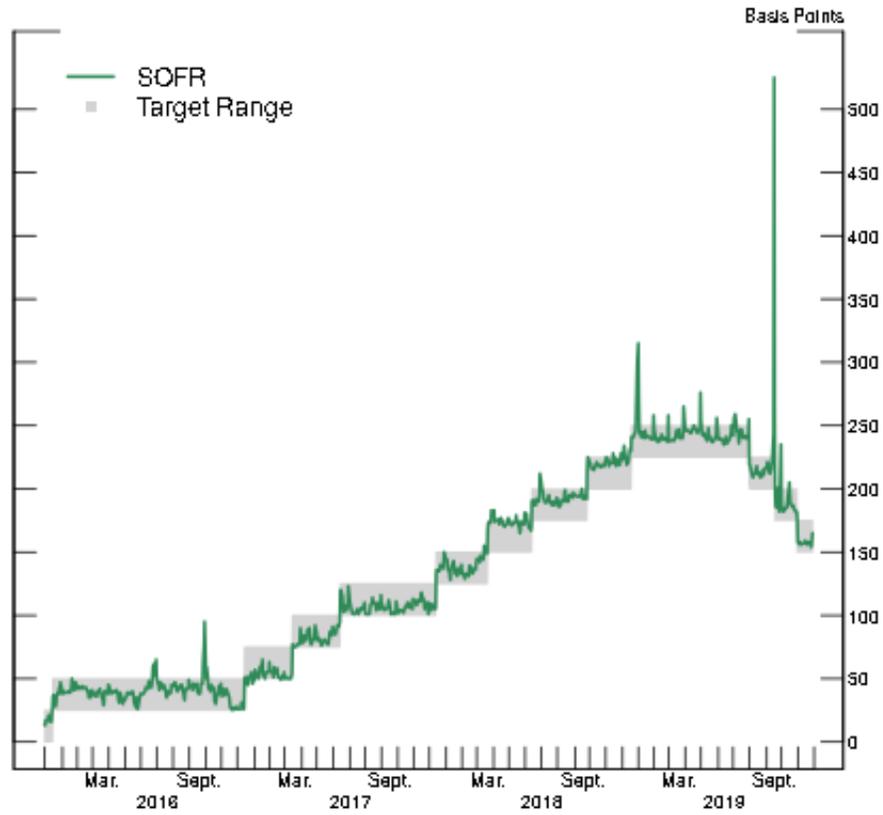
This figure displays the daily between-segment spread for overnight Treasury repo rates for the FICC-cleared and tri-party repo segments between January 1, 2017 and December 31, 2019. Specifically, it shows the daily difference between the volume-weighted average rate in FICC-cleared and the volume-weighted average rate in tri-party. Source: (1) DTCC Solutions LLC, an affiliate of The Depository Trust & Clearing Corporation; (2) Bank of New York Mellon tri-party data.

Figure 5: Volume in FICC-Cleared Sponsored Repo Lending by Money Market Funds



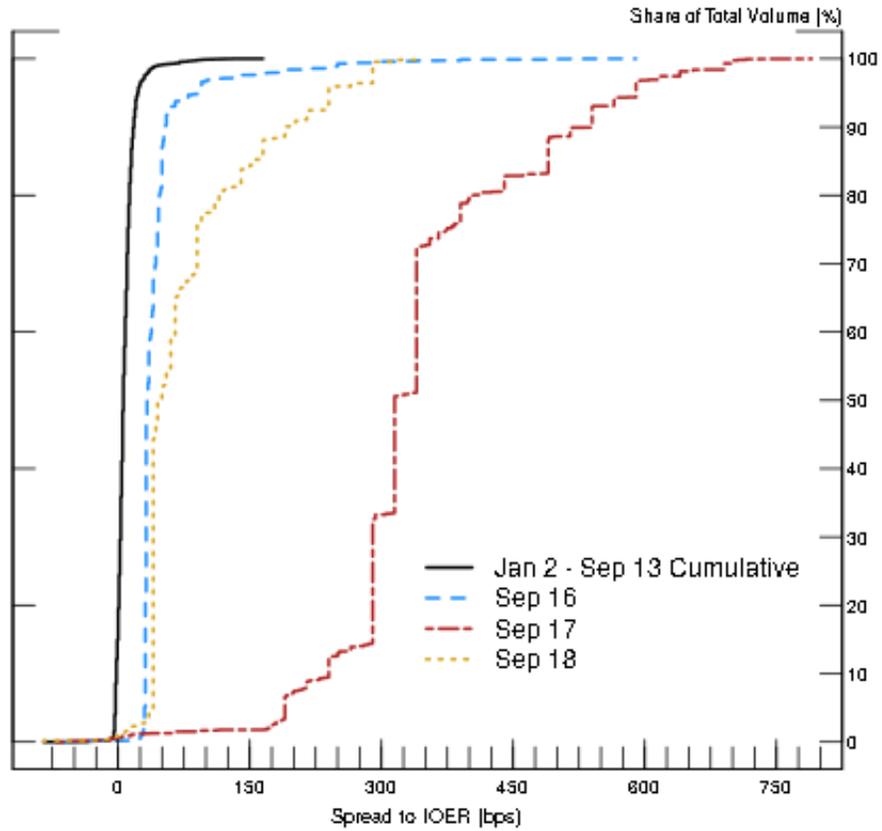
This figure shows month-end lending volumes in the sponsored service of FICC-cleared repo by MMFs using the SEC N-MFP filing data. Through sponsored service, non-FICC members can participate in the FICC-cleared segment via a sponsor (typically a dealer). Source: SEC N-MFP public data.

Figure 6: SOFR



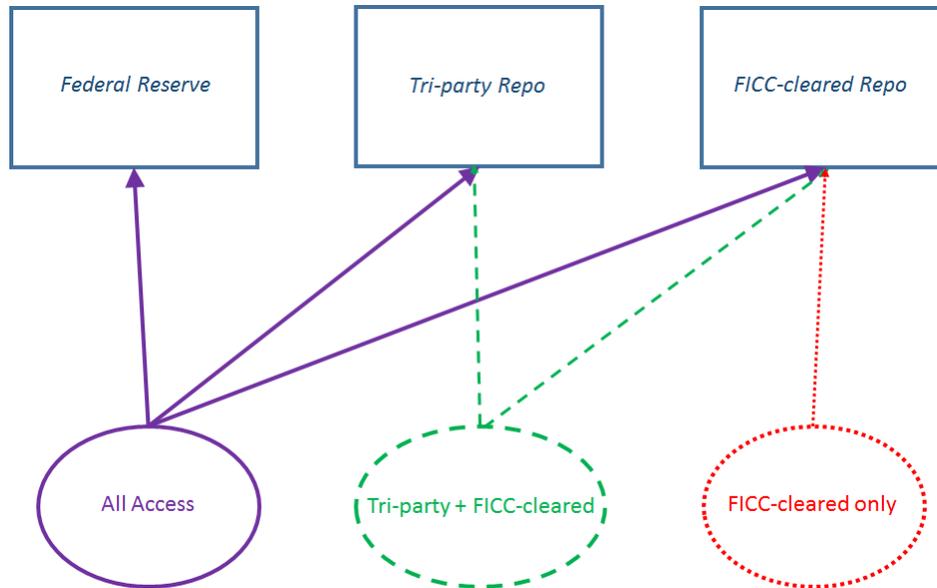
This figure shows the secured overnight financing rate (SOFR) and the Federal Reserve's target range for the federal funds rate between December 1, 2015 and November 29, 2019. Source: The data are from the Federal Reserve Bank of New York and the Board of Governors and are available on their public websites.

Figure 7: Distribution of SOFR Volumes



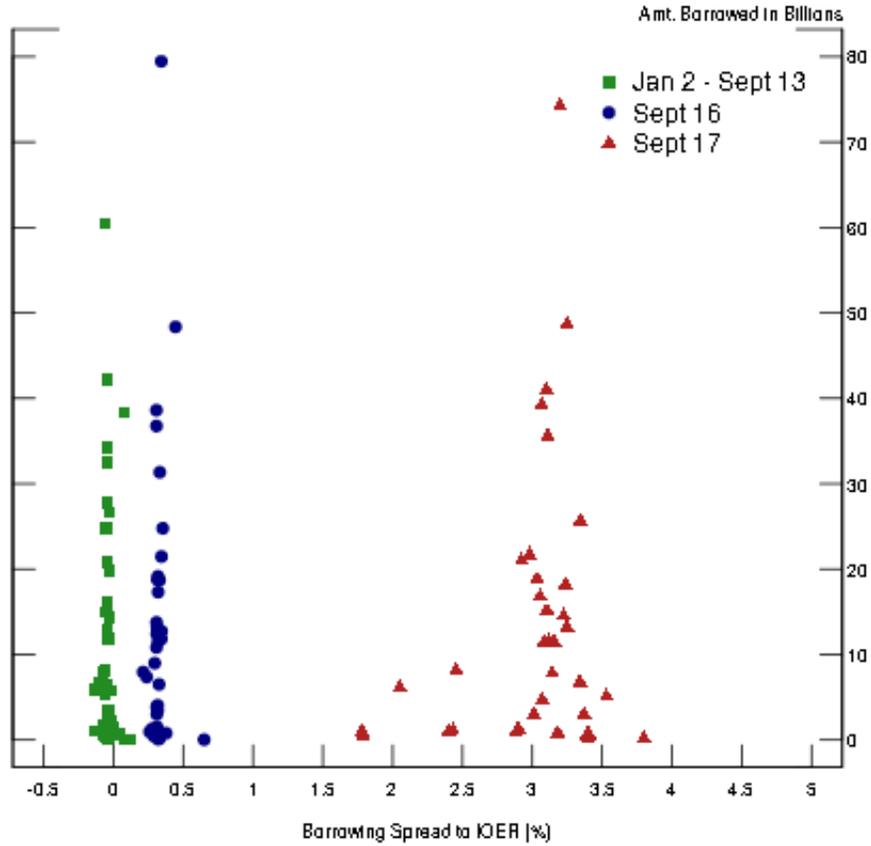
This figure displays the distribution of the secured overnight financing rate (SOFR) against SOFR volumes over four date ranges: “normal” days between January 2, 2019 and September 13, 2019; September 16, 2019; September 17, 2019; and September 18, 2019. Source: (1) DTCC Solutions LLC, an affiliate of The Depository Trust & Clearing Corporation; (2) Bank of New York Mellon tri-party data.

Figure 8: FICC-Cleared Participant Types Based on Access



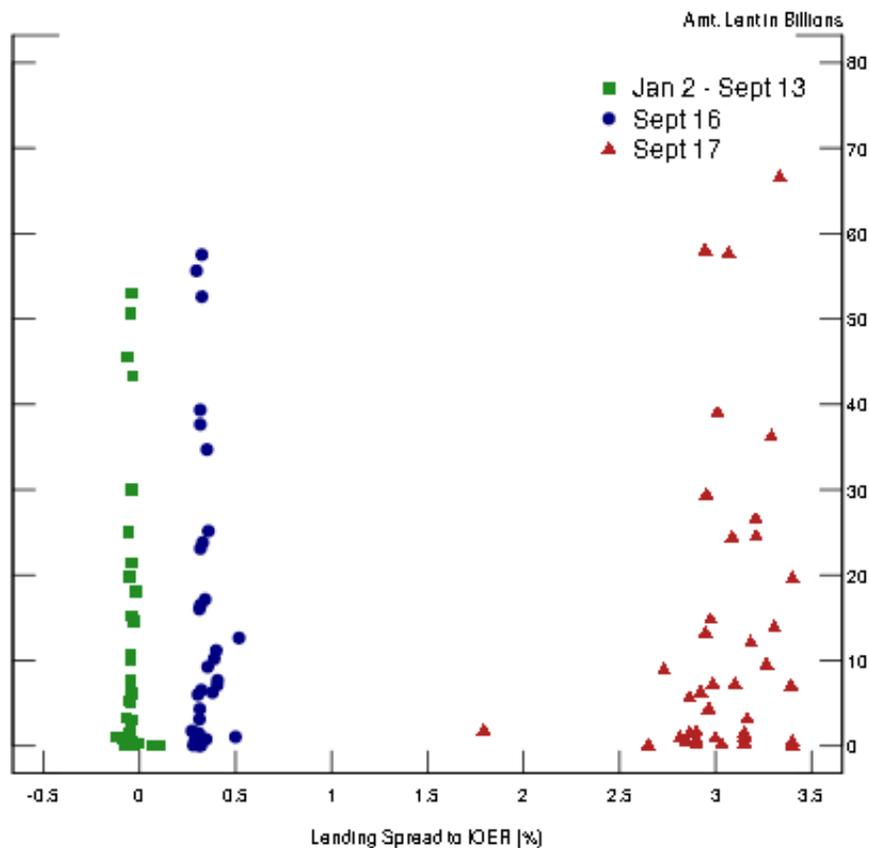
This figure illustrates how we define participant types in the FICC-cleared repo segment. All-access participant can trade in both the tri-party and FICC-cleared repo segments, as well as participate in Federal Reserve repo operations. Tri-party + FICC-cleared participants can trade in both the tri-party and FICC-cleared repo segments, but cannot participate in Federal Reserve repo operations. FICC-cleared only participants can only trade in FICC-cleared repo, not in the tri-party segment. Source: The list of FICC-cleared participants are publicly available at <https://www.dtcc.com/client-center/ficc-gov-directories>.

Figure 9: Borrowing Dynamics in Tri-party Repo



This figure displays the borrowing spread against total volume for each borrower in the tri-party repo segment across three date ranges: a “normal” period between January 2 and September 13, 2019 (squares); September 16, 2019 (circles); and September 17, 2019 (triangles). The borrowing spread is defined as the volume-weighted average interest rate a borrower paid minus the interest rate on excess reserves (IOER). Source: The data are from the Bank of New York Mellon tri-party data.

Figure 10: Lending Dynamics in Tri-party Repo



This figure displays the lending spread against total volume for each lender in the tri-party repo segment across three date ranges: a “normal” period between January 2 and September 13, 2019 (squares); September 16, 2019 (circles); and September 17, 2019 (triangles). The lending spread is defined as the volume-weighted average interest rate a lender gained minus the interest rate on excess reserves (IOER). Source: The data are from the Bank of New York Mellon tri-party data.

Table 1: Factors that Affect SOFR-IOER Spread

	(1) Spread
Mid-month	0.062*** (9.79)
Month-End	0.151*** (4.71)
First day of month	-0.055** (-2.42)
Observations	361
R^2	0.3501

This table displays a daily time series regression on three indicator variables that represent important seasonal events in repo markets: mid-month, month-end, and the first day of the month. The sample is April 2, 2018 to September 13, 2019. The dependent variable is the change in the spread between the secured overnight financing rate (SOFR) and the interest rate on excess reserves (IOER). t statistics are shown in parentheses. Statistical significance: *** $p \leq .01$, ** $p \leq .05$, * $p \leq .10$. Source: The data are from the Federal Reserve Bank of New York and are available at <https://apps.newyorkfed.org/markets/autorates/SOFR>.

Table 2: Summary Statistics on the Number of Participants

<i>Tri-party Repo</i>	
Lenders	45
Borrowers	29
Borrower-Lender Pairs	535
<i>FICC-cleared Repo</i>	
Total Participants	134
All-Access Participants	31
FICC+Tri-party Participants	73
Sponsored Members	11
FICC-only Participants	30

This table displays the number of participants in the tri-party and FICC-cleared repo segments. Participant types in FICC-cleared are defined in Section 4. Sponsored Members are a subset of FICC+Tri-party Participants. Source: The list of FICC-cleared participants are publicly available at <https://www.dtcc.com/client-center/ficc-gov-directories>. The number of tri-party repo participants are from the Bank of New York Mellon tri-party data.

Table 3: Volumes and Within-FICC Spread in FICC-Cleared Repo in mid-September

	(1) Borrowing Volume	(2) Lending Volume	(3) Within-FICC Spread
All-access x Sep. 16-17	-0.109** (-2.27)	-0.026 (-0.41)	0.981*** (12.91)
FICC+triparty x Sep. 16-17	-0.037 (-0.76)	-0.115* (-1.76)	0.961*** (12.65)
Borrowing Rate	0.031 (1.63)		
Lending Rate		0.008 (0.56)	
Net Volume			-0.484*** (-24.19)
Participant Type FE	Yes	Yes	Yes
Daily Time FE	Yes	Yes	Yes
Observations	2229	2230	2202
R^2	0.9905	0.9914	0.9545

This table displays the regression results of the borrowing and lending volume in the FICC-cleared segment and the within-FICC spread on September 16-17. The data are daily positions in the FICC-cleared segment between January 1, 2017 and December 31, 2019. *Within-FICC Spread* is defined as the volume-weighted representative lending rate minus the volume-weighted representative borrowing rate, for each participant type within the FICC-cleared segment. *Net Volume* is the logged value of total borrowing minus total lending for each participant type. t statistics are shown in parentheses. Statistical significance: *** $p \leq .01$, ** $p \leq .05$, * $p \leq .10$. Source: DTCC Solutions LLC, an affiliate of The Depository Trust & Clearing Corporation.

Table 4: Spread in Tri-party Repo in mid-September

	(1) Spread	(2) Spread
Sept. 16-17	2.922*** (21.01)	2.789*** (21.20)
Sept. 18	-0.188 (-0.73)	-0.223 (-0.58)
Volume	-0.002 (-1.57)	-0.003** (-2.37)
Spread _{t-1}	0.265*** (3.38)	0.283** (2.29)
Dealer Controls	No	Yes
AR(1)	Yes	Yes
Dealer FE	Yes	Yes
Daily Time FE	Yes	Yes
Observations	18206	13936
R^2	0.9613	0.9698

This table displays the regression results of the spread paid by dealers on September 16-17 in the tri-party segment. The data are daily overnight Treasury tri-party repo transactions collapsed to the dealer level between January 1, 2017 and October 31, 2019. *Spread* is the difference between the volume-weighted average borrowing rate in tri-party minus the interest rate on excess reserves (IOER). The control variable *Volume* is logged. Dealer controls include the dealer's market share in the tri-party repo segment, logged total assets, and its dependence on short-term funding, as defined in Section 4.3. Standard errors are clustered at the dealer level. t statistics are shown in parentheses. Statistical significance: *** $p \leq .01$, ** $p \leq .05$, * $p \leq .10$. Source: Bank of New York Mellon tri-party data.

Table 5: Volumes within Trading Relationship in Tri-party Repo in mid-September

	(1)	(2)
	Volume	Volume
dealer==1 x Sept. 16-17	-0.136 (-1.03)	-0.049 (-0.43)
dealer==2 x Sept. 16-17	-0.150* (-1.81)	-0.144* (-1.89)
dealer==3 x Sept. 16-17	-0.372 (-1.47)	-0.312 (-1.47)
dealer==4 x Sept. 16-17	-0.032 (-0.23)	-0.015 (-0.11)
dealer==5 x Sept. 16-17	-0.052 (-0.64)	-0.112 (-1.39)
dealer==6 x Sept. 16-17	-0.377* (-1.84)	-0.289 (-1.49)
dealer==7 x Sept. 16-17	-0.245* (-1.90)	-0.241** (-2.10)
dealer==8 x Sept. 16-17	-0.134 (-1.14)	-0.080 (-0.85)
dealer==9 x Sept. 16-17	-0.148 (-0.64)	-0.123 (-0.55)
dealer==10 x Sept. 16-17	-0.510* (-1.95)	-0.421* (-1.73)
dealer==11 x Sept. 16-17	-0.463 (-1.27)	-0.196 (-0.63)
Spread	-0.862 (-1.52)	-0.762 (-1.52)
Dealer Controls	No	Yes
Complex Controls	No	Yes
Dealer-Complex Controls	No	Yes
AR(1-3)	Yes	Yes
Dealer FE	Yes	Yes
Complex FE	Yes	Yes
Dealer-Complex FE	Yes	Yes
Observations	177145	133918
R^2	0.9575	0.9658

The data are daily overnight Treasury tri-party repo transactions between January 1, 2017 and October 31, 2019. We only show dealer fixed effect interactions with a dummy that equals 1 when t is September 16-17, 2019 for 11 of the 29 dealers for brevity. These dealer fixed effect interactions are picked randomly. Dealer controls include the dealer's market share in the tri-party Treasury repo market, total assets, and dependence on short-term funding. MMF complex controls include total assets under management, the market value of total Treasury repo position, and the market value of total Treasury security position. Dealer-complex controls include all the borrower-lender variables described in Section 4.3. We include dealer, MMF complex, dealer-MMF complex, and time fixed effects. Standard errors are clustered at the relationship level. t statistics are shown in parentheses. Statistical significance: *** $p \leq .01$, ** $p \leq .05$, * $p \leq .10$. Source: Bank of New York Mellon tri-party data.

Table 6: MMF Bargaining Power

	(1) Spread
SOFR goes Public	-0.027*** (-40.76)
Expansion of Sponsored Repo	-0.017*** (-9.32)
Mid-Month	-0.001 (-0.70)
Month-End	0.002 (0.87)
First Day of Month	0.002 (0.77)
Observations	674
R^2	0.5088

This table shows a daily time series regression between January 1, 2017 and September 13, 2019. The dependent variable is the 30-day rolling standard deviation of the FICC/tri-party spread. The control variables include three indicator variables that represent important seasonal events in repo markets: mid-month, month-end, and the first day of the month. Additionally, *SOFR goes Public* equals 1 between April 2, 2018 and March 1, 2019 and *Expansion of Sponsored Repo* equals 1 after March 1, 2019. *t* statistics are shown in parentheses. Statistical significance: *** $p \leq .01$, ** $p \leq .05$, * $p \leq .10$. Source: (1) DTCC Solutions LLC, an affiliate of The Depository Trust & Clearing Corporation; (2) Bank of New York Mellon tri-party data.

Table 7: Relationship Strength and MMF Bargaining Power

	(1) Bet-Seg Spread	(2) Bet-Seg Spread
Borrower's Share of Lender's Bus. x SOFR Public	-0.423** (-2.44)	-0.755*** (-4.32)
Lender's Share of Borrower's Bus. x SOFR Public	-0.103 (-1.35)	-0.162** (-2.21)
Days in Relationship x SOFR Public	-0.045*** (-6.12)	-0.047*** (-5.66)
Borrower's Share of Lender's Bus. x Expansion Sponsored	-0.480** (-2.10)	-0.977*** (-3.84)
Lender's Share of Borrower's Bus. x Expansion Sponsored	-0.082 (-0.76)	-0.177* (-1.72)
Days in Relationship x Expansion Sponsored	-0.069*** (-6.63)	-0.064*** (-5.62)
Borrower's Share of Lender's Business	-0.491*** (-2.76)	-0.668*** (-5.24)
Lender's Share of Borrower's Business	-0.599*** (-6.25)	-0.490*** (-4.13)
Days in Relationship	0.016** (2.56)	0.022*** (3.39)
Dealer Controls	No	Yes
Complex Controls	No	Yes
Dealer-Complex Controls	No	Yes
Dealer-Complex FE	Yes	Yes
Daily Time FE	Yes	Yes
Observations	167858	127799
R^2	0.9374	0.9413

This table shows a daily panel regression between January 1, 2017 and September 13, 2019. The dependent variable is the between-segment spread; that is, the volume-weighted representative lending rate in FICC-cleared by participant type minus the volume-weighted average borrowing rate in tri-party by dealer. *SOFR Public* equals 1 between April 2, 2018 and March 1, 2019 and *Expansion Sponsored* equals 1 after March 1, 2019. The relationship variables of interest are the borrower's share of the lender's business, the lender's share of the borrower's business, and the number of days the borrower and lender have had a relationship, as defined in Section 4.3. We include borrower, lender, and borrower-lender fixed effects, as well as daily time fixed effects. t statistics are shown in parentheses. Statistical significance: *** $p \leq .01$, ** $p \leq .05$, * $p \leq .10$. Source: (1) DTCC Solutions LLC, an affiliate of The Depository Trust & Clearing Corporation; (2) Bank of New York Mellon tri-party data.

Table 8: Dealer Balance Sheet Constraints

	(1)	(2)
	Bet-Seg Spread	Bet-Seg Spread
Unconstrained Dealer x SOFR Public	-0.065** (-1.99)	-0.170*** (-5.36)
Unconstrained Dealer x Expansion Sponsored	-0.079* (-1.83)	-0.182*** (-4.32)
Dealer Controls	No	Yes
Complex Controls	No	Yes
Dealer-Complex Controls	No	Yes
Observations	144133	112024
R^2	0.9145	0.9173

This table shows a daily panel regression between January 1, 2017 and September 13, 2019. The dependent variable is the between-segment spread; that is, the volume-weighted representative lending rate in FICC-cleared by participant type minus the volume-weighted average borrowing rate in tri-party by dealer. *Unconstrained Dealer* equals 1 for dealers that do not face binding balance sheet constraints, as defined by those dealers that use Fed repo operations between September 17 and October 11, 2019. *SOFR Public* equals 1 between April 2, 2018 and March 1, 2019 and *Expansion Sponsored* equals 1 after March 1, 2019. We include borrower, lender, and borrower-lender fixed effects, as well as daily time fixed effects. t statistics are shown in parentheses. Statistical significance: *** $p \leq .01$, ** $p \leq .05$, * $p \leq .10$. Source: (1) DTCC Solutions LLC, an affiliate of The Depository Trust & Clearing Corporation; (2) Bank of New York Mellon tri-party data.

Table 9: Dealer Balance Sheet Constraints in mid-September

	(1) Bet-Seg Spread	(2) Bet-Seg Spread
Unconstrained Dealer x Sep. 16-17	-0.070 (-1.16)	-0.068 (-1.02)
Dealer Controls	No	Yes
Complex Controls	No	Yes
Dealer-Complex Controls	No	Yes
Observations	160542	124601
R^2	0.9112	0.9133

This table shows a daily panel regression between January 1, 2017 and December 31, 2019. The dependent variable is the between-segment spread; that is, the volume-weighted representative lending rate in FICC-cleared by participant type minus the volume-weighted average borrowing rate in tri-party by dealer. *Unconstrained Dealer* equals 1 for dealers that do not face binding balance sheet constraints, as defined by those dealers that use Fed repo operations between September 17 and October 11, 2019. We include borrower, lender, and borrower-lender fixed effects, as well as daily time fixed effects. t statistics are shown in parentheses. Statistical significance: *** $p \leq .01$, ** $p \leq .05$, * $p \leq .10$. Source: (1) DTCC Solutions LLC, an affiliate of The Depository Trust & Clearing Corporation; (2) Bank of New York Mellon tri-party data.

Appendix

7.1 Robustness Analysis

7.1.1 Using the GCF-BNYM spread

To explore the possibility of FICC/tri-party spread responding to other events in repo markets that were correlated with the timing of SOFR going public or the expansion of sponsored repo, we perform a robustness check for the results displayed in Table 6. This appendix presents the results of estimating Equation 8 using the standard deviation of the GCF-BNYM spread as the dependent variable.

The GCF-BNYM spread represents an interdealer market rate minus the tri-party rate provided by BNYM. This spread has been publicly available to market participants since at least 2010. The GCF market, as discussed in Section 2, is a small interdealer market and accounts for a very small portion of overnight Treasury repo activity, about \$50 billion per day during our sample period. If the release of SOFR or expansion of sponsored repo provided no additional information about the repo market, we would expect no changes to the standard deviation of the GCF-BNYM spread since this spread was already publicly available.

Table A.1 shows the results of estimating Equation 8 where the dependent variable is replaced with the 30-day rolling standard deviation of the GCF-BNYM spread. We see that the standard deviation of the GCF-BNYM spread increased by 2.3 basis points after SOFR went public, and declined by 2 basis points after the expansion of sponsored repo. The increased volatility of the GCF-BNYM spread was likely due to new information becoming available about the FICC-cleared segment. By the time sponsored repo expansion occurred,

the GCF-BNYM spread had already anchored to SOFR, which may explain the reduction in volatility offsetting the initial increase.

Table A.1: MMF Bargaining Power
Robustness with GCF-BNYM Spread

	(1) GCF-BNYM Spread
SOFR goes public	0.023*** (2.76)
Expansion of Sponsored Repo	-0.020*** (-8.47)
Mid-Month	-0.008 (-0.69)
Month-End	0.007 (0.48)
First Day of Month	0.010 (0.65)
Observations	674
R^2	0.0449

This table shows a daily time series regression between January 1, 2017 and September 13, 2019. The dependent variable is the 30-day rolling standard deviation of the GCF minus BNYM tri-party spread. The control variables include three indicator variables that represent important regular events in repo markets: mid-month, month-end, and the first day of the month. Additionally, *SOFR goes Public* equals 1 between April 2, 2018 and March 1, 2019 and *Expansion of Sponsored Repo* equals 1 after March 1, 2019. t statistics are shown in parentheses. Statistical significance: *** $p \leq .01$, ** $p \leq .05$, * $p \leq .10$. Source: The data are publicly available at <https://www.dtcc.com/charts/dtcc-gcf-repo-index>.