

# Lender Preference, Borrower Market Power, and the Effect of RRP\*

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## Abstract

I model and structurally estimate the equilibrium rates and volumes on the Triparty repo market to study how imperfect competition affects monetary policy implementation. Even in this systemically important market, where seemingly homogeneous repos trade, I document persistent rate differences paid by dealers. I therefore characterize the Triparty market as cash-lenders allocating their portfolios among differentiated dealers who set repo rates. I find that cash-lenders' aversion to concentrated portfolios gives dealers substantial market power: dealers borrow at rates that are 21 bps lower than their marginal benefit from intermediating borrowed funds, inserting a considerable wedge in wholesale funding rates. I show through counterfactual analyses the effect of the Federal Reserve's Reverse Repo Facility (RRP). Compared to its absence, the RRP raised the Triparty repo rate by 15 bps and tightened dealers' markdowns by 8 bps between 2014 and 2017; these effects were amplified by the Money Market Fund Reform.

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*Keywords:* Triparty repo, market power, portfolio allocation, monetary policy, Reverse Repo Facility (RRP), money market fund reform

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# 1 Introduction

Monetary policy implementation hinges on incentivizing private agents to set market rates in accordance with the policy rate. This paper studies how imperfect competition in the Triparty repo market affects the relationship between policy rates and market rates. A key part of the money and bond market, the \$2 trillion Triparty repo market underpins the working of a large volume of securities, including Treasury and Agency mortgage bonds (see the studies by [Copeland et al. \(2014\)](#), [Krishnamurthy et al. \(2014\)](#)). Every day in the Triparty repo market, experienced and sophisticated actors on both sides of the market borrow and lend cash using homogeneous repurchase agreements (repo). Nevertheless, when cash-lenders (e.g., BlackRock) lend to different dealers simultaneously (e.g., Goldman Sachs and Wells Fargo), the rates that cash-lenders accept show persistent cross-dealer differences, suggesting imperfect competition.

Imperfect competition in the Triparty market hinders monetary policy implementation by obfuscating the true condition in wholesale funding markets. The Triparty market is where dealers source the cash that they intermediate to financial market participants seeking to purchase securities with leverage. Activities on the Triparty market are therefore barometers of funding conditions facing not just dealers but also the broader market. Indeed, these activities enter the construction of SOFR, the new reference rate that replaces LIBOR as the benchmark interest rate for dollar-denominated derivatives and loans.<sup>1</sup> Yet imperfect competition would mean that, first, the level of the Triparty repo rate is but a crude measure of the true cost of capital facing market participants, and that, second, movements of the Triparty repo rate embed in them unwanted fluctuations

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<sup>1</sup>Three published reference rates use the Triparty repo rates in their construction: the Secured Overnight Financing Rate (SOFR), the Broad General Collateral Rate (BGCR), the Triparty General Collateral Rate (TGCR). SOFR is the preferred replacement for USD LIBOR.

in dealers' market power. As activities on the Triparty market are readily observable but the subsequent intermediation is opaque, policy implementation can be enhanced by understanding the nature and the extent of imperfect competition in the Triparty market.

To quantify the degree of competition and the impact of market power on rates, I develop and structurally estimate the first equilibrium model of the Triparty market. My estimates reveal that the rate dispersion observed on Triparty belies a substantial market power held by dealers who are cash-borrowers. Between 2011 and 2017, dealers borrowed at rates that were on average 21 bps lower than their estimated marginal benefit from intermediation, thereby claiming 78% of a 26-bps total surplus. These markdowns reveal a considerable but not empirically observable wedge between the Triparty repo rates paid by dealers and the funding rates dealers intermediate to financial market participants. The Triparty dealers' market power stems from Triparty cash-lenders' aversion to portfolio concentration. In this competitive environment, monetary policy tools such as the Federal Reserve's Overnight Reverse Repo Facility (RRP) are critical for both the level of the Triparty repo rate and the size of dealers' markdowns. Without the RRP, which constrains dealers' market power by providing an alternative outside option to Triparty cash-lenders, the median Triparty repo rate would have been 15.3 bps lower between 2014 and 2017. The rate intermediated by dealers to the broader financial market, however, would drop by only 7.7 bps, as 49% (7.6 bps) of the counterfactual rate drop reflects dealers' widening markdowns, further broadening the wedge in wholesale funding rates.

I start by documenting three new empirical facts about the Triparty repo market. First, cash-lenders (henceforth, lenders) simultaneously and consistently accept different repo rates against contracts that differ only in the identity of the cash-borrowers (henceforth, borrowers). Second, borrowers' identities drive repo rate dispersion both in the

cross-section and in the time-series; in contrast, different lenders that lend to the same borrower do so at rates that are statistically indistinguishable. Third, larger lenders connect to more borrowers – not to “rate shop” but – to spread out lending, giving smaller shares of their portfolios to each borrower.

These patterns provide a new perspective on the workings of the Triparty market. First, because Triparty lenders and borrowers repeatedly trade with each other, lending at persistently different rates likely reflects lenders’ perception that borrowers are differentiated. I speculate that lenders have a strong preference for stable investment opportunities, and therefore discriminate between borrowers that vary in how consistently they use their scarce balance sheet to take on repo loans. Second, although repo contracts are bilaterally determined, the overwhelming importance of between-borrower variation in explaining repo rate dispersion, hints at a market where borrowers set borrower-specific repo rates for all lenders. Finally, in constructing their portfolios, lenders seem to exhibit a size-dependent aversion to concentration: the larger they are, the more averse they are to lending too much of their portfolio to any one borrower. Such an aversion could stem from fears for operational risks, in particular the fire sale risks that ensue from an operational disruption.

These empirical insights motivate me to model the Triparty market using a supply-and-demand framework, where the “goods” traded is the cash extended against repo collateral. On the supply side, lenders allocate their cash among differentiated borrowers who seek to obtain cash via repo. The lender’s utility reflects an aversion to concentration and a non-pecuniary preference for stability in lending opportunities. These two forces determine the lender’s optimal lending quantity and his sensitivity to repo rate changes. On the demand side, borrowers appeal to their differentiation and set repo rates as local

monopsonies. The borrower’s utility is linear in her profit. At the borrower’s optimum, she offers a repo rate that is marked down from her marginal benefit from intermediation.<sup>2</sup> The ability to build in a markdown is the borrower’s market power, and the size of her markdown is a function of the lender’s supply elasticity. At a given quantity of repo funding, the less the lender reacts to repo rate changes, the more the borrower can mark down the rate she pays. Thus, the model embeds two forces that could contribute to the presence of imperfect competition: differences in the lender’s preference for stability and differences in the lender’s aversion to concentration.

The key to separately identifying the forces in my model is to understand how lenders respond to rate changes, which directly informs the concentration aversion parameter. Intuitively, when a borrower experiences a funding shock and raises her repo rate to attract more cash, the lender would want to take advantage of the more favorable rate by lending more to this borrower. Yet if the lender has an acute aversion to concentration, then his response will be muted because he does not want to have too much repo invested with any one single borrower. I estimate lender’s semi-elasticity using offerings at Treasury auctions as an instrumental variable.<sup>3</sup> Over my sample period, a \$40 billion (1 standard deviation) increase in the amount offered in non-bill Treasury security auctions is associated with an average increase of \$0.65 billion in a borrower’s repo borrowing.<sup>4</sup> To raise \$0.65b in additional funding (about 4%), a borrower needs to raise the repo rate she pays by about 1 bp. This estimate is in-line with the recent funding flow to the RRP

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<sup>2</sup>Throughout, I refer to the lender as “he” and refer to the borrower as “she”.

<sup>3</sup>The U.S. Treasury Department conducts periodic auctions of Treasury securities. The quantity of this auction influences the amount of repo borrowings sought by dealers because dealers buy securities and finance their purchase with repo. At the same time, the amount *offered* – not purchased – at each auction is likely driven by the Treasury department’s fiscal concerns and plausibly exogenous to lenders’ supply shocks. To further isolate the impact from Treasury-induced repo borrowing, my instrument purposely excludes auctions of Treasury bills, which can be purchased by money market funds who are cash-lenders on Triparty.

<sup>4</sup>The total increase in Triparty borrowing is about \$11 billion for every \$40 billion of auction offer.

following an unexpected rate increase in June 2021.<sup>5</sup> It also signals relative inelasticity in the Triparty market compared to other large markets such as the one for Treasury securities (e.g., [Greenwood et al. \(2015\)](#), [Bernanke et al. \(2004\)](#), [Duffee \(1996\)](#)).<sup>6</sup>

Leveraging moments such as the IV-estimated lender semi-elasticity, I estimate my model parameters using indirect inference and maximum likelihood. My parameter estimates accord with the notion that lenders exhibit size-dependent aversion to concentrated portfolios, thus purposely spreading out their lending. This aversion leads to lenders' relatively inelastic responses in volume to repo rate changes, and grants borrowers market power. The magnitude of borrowers' market power also depends on lenders' non-pecuniary preference. Consistent with the conjecture that these preferences capture a taste for stable investment opportunities, the recovered preference values show a strong correlation with measures of borrower reliability. On average, I calculate that the repo rates paid by borrowers during the sample period reflect a 20.7 bps markdown from borrowers' marginal benefit from intermediation. Compared to the 5.7 bps spread between the repo rate and the lenders' outside option, borrowers command 78% of the 26.4 bps total surplus.

In light of the imperfect competition in the Triparty market, I ask, what would have happened to Triparty borrowers' markdowns if the Overnight Reverse Repo Facility did not exist? First introduced in 2013, the RRP is a new monetary policy tool that helped the Federal Reserve (Fed) to successfully raise the interest rate four times between 2015

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<sup>5</sup>On June 17, 2021, the repo rate at the RRP increased unexpectedly from 0 to 5 bps. The volume of repo placed at the RRP increased from \$520.9b on June 16, 2021 to \$755.8b on June 17, 2021. The \$225b overnight increase relative to the total size of Triparty Treasury repo, which was \$1628b as of June 9, 2021, implies an elasticity of 2.9% per basis point increase. As the RRP is the lender's alternative to lending to repo borrowers (see Section 5.2 for more discussion), the lenders' sensitivity to changes in the RRP rate is also the lenders' sensitivity to changes in the borrowers' repo rates.

<sup>6</sup>As an example, [Greenwood et al. \(2015\)](#) estimates that a 1 percentage point decrease in  $\frac{\Delta \text{Treasury}}{\text{GDP}}$  leads to 38.6 bps decrease in the two-week Treasury yield. The average annual GDP between 2011 and 2017 is \$18.7T. This implies that, over my sample period, 1 bp change in yield is associated with \$4.8b change in volume. This response is much higher than in the Triparty market (\$0.6b for 1 bp).

and 2017. The RRP works by allowing Triparty lenders to place repo with the Fed, giving lenders an alternative to lending to repo borrowers. If in lieu of the RRP, lenders placed cash not lent to repo borrowers in Treasury bills, then the equilibrium median repo rate, allowing both the Triparty market and the Treasury bills market to adjust, would have been 15 bps lower than the historical rate, putting it at 11 bps below the lower bound of the Federal Reserve’s policy target. Critically, the rate intermediated from borrowers to the broader financial society does not decline commensurately: the intermediated rate drops by only 7.7 bps, while the borrowers’ markdowns widen by 7.6 bps, broadening the wedge in wholesale funding rates.

How the RRP affects the Triparty market in fact depends on the confluence of policies. Case in point: the 2016 Money Market Fund Reform shifted the composition of lenders on the Triparty market and consequently increased the amount of funding available to borrowers. Through counterfactual analyses, I show that this Reform deepened lenders’ reliance on the RRP. Without the Reform, the RRP would have narrowed borrowers’ markdowns by 6 instead of 8 bps. This 25% difference underscores the need to understand how policies affect intermediaries’ competitive environment both separately and jointly.

This paper contributes to the existing literature in four ways. To start, it offers the first equilibrium characterization of a key funding market and pioneers the application of demand modeling to the over-the-counter (OTC) literature. The Triparty market has long drawn the attention of scholars (e.g. [Krishnamurthy et al. \(2014\)](#), [Copeland et al. \(2014\)](#), [Hu et al. \(2017\)](#), [Aldasoro et al. \(2019\)](#), [Han and Nikolaou \(2016\)](#), [Weymuller \(2013\)](#)). This paper not only enriches the understanding of the Triparty market by documenting new empirical facts, but also provides the first joint determination of rate and volume in a structural model that captures these facts. To do so, this paper departs from the

traditional search framework ([Duffie et al. \(2005\)](#), [Hendershott et al. \(2020\)](#)) and tailors a demand-system to the Triparty market. Moreover, in contrast to the discrete choice model increasingly employed in finance ([Kojen and Yogo \(2018\)](#), [Buchak et al. \(2018\)](#), [Benetton \(2021\)](#)), the lender’s model in this paper emphasizes preferences that lead to simultaneous selection of multiple choices at the optimum. My modeling approach takes inspiration from [Martin and Yurukoglu \(2017\)](#), [Crawford et al. \(2018\)](#), and [Kim et al. \(2002\)](#) in the industrial organization literature.

The estimated structural model in this paper provides a new method for evaluating monetary policy tools, and the findings surface the RRP’s role in limiting dealers’ (borrowers’) market power. The Triparty market is one of the few markets in which the Fed directly operates to implement monetary policies. Although there is a long line of work on traditional monetary policy tools such as the Federal Funds Rate, research that focuses on newer tools such as the RRP is relatively sparse. My examination of the RRP’s effect through counterfactual analyses is distinct from the approaches taken by existing studies of the RRP ([Anderson and Kandrak \(2017\)](#), [Anbil and Zeynep \(2018\)](#), [Infante \(2020\)](#), [Ahnert and Macchiavelli \(2021\)](#), [Chen et al. \(2016\)](#), [Klee et al. \(2019\)](#), [Frost et al. \(2015\)](#)). I’m able to stress the RRP’s effect in limiting dealers’ market power and consequently the wedge in overnight funding rates. I’m moreover able to demonstrate how the effect of the RRP on the competitive environment is modulated by other policies such as the 2016 Money Market Fund Reform.

This paper is the first to quantify the substantial market power in a short-term wholesale funding market and it explores lenders’ preferences as the source of dealers’ market power. My results complement a recent literature that demonstrates the presence of intermediary market power in other OTC markets, such as the European OTC repo



([Eisenschmidt et al. \(2021\)](#)), Canadian Treasury auctions ([Allen and Wittwer \(2021\)](#)), and the foreign exchange market ([Wallen \(2020\)](#)). Compared to these studies, this paper quantifies the extent of dealers market power, and it moreover highlights a novel source of market power. The Triparty dealers' market power owes not to quarter-end implementation of regulations that limit dealer participation, but instead to longstanding preferences of the lender. The preferences explored in this paper, in particular, an aversion to concentration motivated by risks that are not credit in nature, could find applications in other centrally-cleared derivatives markets, and beyond the financial system in areas such as supply chain management.

Finally, this paper furthers the understanding of market power's impact on asset prices and monetary policy implementation. The presence of dealers' markdowns create divergence in the cost of capital facing dealers versus the broader wholesale funding market. Quantifying this wedge, on the one hand, offers a new interpretation to observed near-arbitrage spreads in short-term funding markets (e.g., [Fleckenstein and Longstaff \(2020\)](#), [van Binsbergen et al. \(2021\)](#)). On the other hand, it helps interpret movements in new reference rates constructed using Triparty repo activities, which in turn aids the setting of policy targets for these new reference rates. Beyond the short-term wholesale funding market, market power has been shown to impede monetary transmission to the deposit market ([Drechsler et al. \(2017\)](#)), the mortgage bonds market ([Scharfstein and Sunderam \(2017\)](#)), the refinancing market ([Agarwal et al. \(2021\)](#)) and the banking sector ([Wang et al. \(2020\)](#)). Taken together, these papers all point to the importance of financial intermediaries in asset pricing and monetary policy implementation ([He and Krishnamurthy \(2017\)](#), [Duffie and Krishnamurthy \(2016\)](#)). Policies and policy tools ought to therefore be evaluated also by the effect that they have on creating or constraining intermediaries'

market power.

In the next section, I provide details on the Triparty market and the data used to study it. In Section 3, I present and discuss the salient empirical observations that motivate my modeling choices. Then in Section 4, I outline the models for the lender's and the borrower's problem. Estimation of the lender's model and its results are discussed in Section 5. I calibrate the borrower's model before conducting two counterfactual analyses in Section 6. In Section 7, I conclude.

## **2 Triparty repo market and data**

In this section, I highlight the distinct features of the Triparty market, outline the role the Triparty market plays in collateral financing and monetary policy implementation, and describe the data used to study this market.

### **2.1 The Triparty market and the RRP**

Repurchase agreements are contracts between two counterparties to exchange cash against collateral. I refer to the counterparty that provides the cash as the lender, and the counterparty that pledges collateral to get cash as the borrower. The posted collateral, often valued at a haircut, is returned to the borrower when the cash is repaid – with an interest. I refer to the rate used to determine that interest as the repo rate. Since repo lending is secured, repo contracts can differ depending on the collateral used. The Triparty market offers a way to make the OTC repo collateralization more standardized.

The Triparty market derives its name from its institutional set-up. On Triparty, every transaction involves a third agent, who is the clearing bank that handles the logistics of cash and collateral transfers. All Triparty borrowers and the lenders maintain accounts

with the same clearing bank.<sup>7</sup> Once a borrower and a lender agree on the terms of a repo, the clearing bank makes collateral allocation behind-the-scenes and monitors the value of the collateral. Moreover, Triparty repo contracts specify only the class of collateral, e.g., Treasury securities, but not the exact securities used, e.g., CUSIPs of specific five-year on-the-run Treasury securities.<sup>8</sup> These features together make Triparty repo contracts standardized within a collateral class, and make Triparty repo convenient for funding.

Indeed, the Triparty market is a step in the intermediation process that channels cash through the financial system to market participants looking to finance their holdings. Cash-rich individuals and corporations place cash in vehicles such as money market funds (MMFs). MMFs keep a stable fraction of their asset under management (AUM) in overnight cash for liquidity. This overnight cash is lent out via Triparty repo to broker-dealers. Dealers, in turn, use their borrowed cash to either finance their own security holdings or intermediate this funding to their clients in the broader financial market. Every day, over \$2 trillion dollars are injected into the secured market through the Triparty market.

The Federal Reserve (Fed) has long been a keen observer of the Triparty repo market because the Triparty rate affects many other money market rates and security prices. By virtue of being a funding market, conditions on the Triparty market directly affect securities such as Treasury and Agency MBS, which are posted as collateral and thus financed with Triparty lending.<sup>9</sup> Moreover, Triparty repo trades enter into the construction of the Secured Overnight Financing Rate (SOFR), which replaces LIBOR as the new

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<sup>7</sup>The sole Triparty clearing bank in the US is Bank of New York Mellon. J.P. Morgan used to also provide Triparty clearing service for about 15% of the market. It discontinued its service in 2017.

<sup>8</sup>In contrast, repos done outside of the Triparty market allows the borrower and lender to maintain accounts at different custodial banks, and even for “general collateral” repo, the borrower needs to stipulate the CUSIPs of all securities used as collateral.

<sup>9</sup>Treasury or Agency MBS account for over 90% of the collateral used in the Triparty market.

dollar interest rate benchmark, affecting a large swath of dollar-denominated contracts and derivatives.

In September 2013, in anticipation of a change in the stance of monetary policy, the Fed set up an overnight, fixed-rate, full-allotment reverse repo facility (RRP) on the Triparty market.<sup>10</sup> The RRP gives a wide array of Triparty cash lenders<sup>11</sup> the ability to lend to the Fed in the form of overnight repo at a pre-announced interest rate. The Fed gradually increased the RRP’s capacity, and the RRP became seen as a fixture of Triparty in September 2014. When the RRP was first set up in September 2013, access to the facility was capped at \$500 million per eligible lender. This cap was subsequently raised 6 times, eventually reaching \$30 billion per eligible lender by September 2014, at which point the cap no longer seemed binding for any lender. September 2014 was also when the Fed stated in the FOMC’s Policy Normalization Principles and Plans that “the Committee intends to use the RRP facility as a tool to help control the federal funds rate during the normalization of the stance of monetary policy”, further underscoring the Fed’s commitment to the RRP. In effect, by September 2014, Triparty lenders had an attractive alternative to lending to repo borrowers, in the form of the RRP.

## 2.2 Data

To study the Triparty market, I use monthly SEC filings made by MMFs domiciled in the United States. MMFs are the largest class of cash lenders on the Triparty market, accounting for 40% to 60% of all repo transactions. Other Triparty lenders include security lenders, pension funds, insurance companies, and various municipalities with temporary excess cash (Copeland et al. (2012)).

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<sup>10</sup>[https://www.newyorkfed.org/markets/opolicy/operating\\_policy\\_130920.html](https://www.newyorkfed.org/markets/opolicy/operating_policy_130920.html)

<sup>11</sup>[https://www.newyorkfed.org/markets/rrp\\_counterparties](https://www.newyorkfed.org/markets/rrp_counterparties)

MMF are regulated and are required to file monthly N-MFP reports. These filings are snapshots of an MMF’s entire portfolio as of the last business day of each month.<sup>12</sup> In particular, for each repo contract that the MMF has, information is available on the counterparty, the amount, the repo rate,<sup>13</sup> the maturity date, and the collateral type and value.

I obtain all N-MFP reports between 2011 and 2017 from the SEC EDGAR data base, and collapse the filings by money market fund families.<sup>14</sup> Each money market fund family, e.g. BlackRock, can have a number of different money market funds, e.g. government-security only funds vs. tax-exempt funds. Importantly, money market fund families enter into repo contracts on behalf of all funds in the family and then distribute the investment across funds (Copeland et al. (2014)). To analyze the equilibrium rate and volume determination, it is therefore appropriate to consider all funds in the same fund family as one entity.

Money market funds manage their liquidity by keeping a steady fraction of their AUM in overnight cash. As there are limited options to invest cash overnight, Triparty repo, which is typically overnight, forms an important part of MMFs’ overnight portfolio. I explicitly focus on Triparty repo that are overnight in duration.<sup>15</sup>

Triparty repo activities are concentrated in a relatively small set of agents. As Appendix Figure A1 illustrates, over 85% of the activities in the N-MFP filing data are done

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<sup>12</sup>Although N-MFP filings are done monthly, these reports are likely representative of money market funds’ repo activities throughout the month. Anderson et al. (2019) use proprietary data available at the Federal Reserve, and show in Figure 2(b) that repo activities are stable throughout the month, with the exception of window-dressing activities on the last day of the quarter.

<sup>13</sup>Before April 2016, repo rates are not separately reported. I parse the title of each contract to obtain rates where available. To address potential misreporting issues, I winsorize repo rates at 1% and 99%.

<sup>14</sup>My sample ends in 2017 because I’m interested in the effect of imperfect competition in an abundant reserve regime. The Fed started shrinking its balance sheet in 2018.

<sup>15</sup>As the N-MFP reports the maturity date without reporting the start date, I identify overnight contracts as those that mature on the first business day of the following month. This approach is universal in papers that use N-MFP filing data. See Aldasoro et al. (2019) for discussions of potential shortcomings.

by 18 MMFs and 20 dealers. My analysis thus focuses on these agents. My final data set is a MMF-dealer-month panel of repo transactions from January 2011 through December 2017 on 84 month ends, for a total of 14,571 observations.

I supplement the data from N-MFP filings with the Federal Reserve’s releases on repo and RRP activities, TreasuryDirect’s reporting of Treasury securities auctions, and CDS pricing from Markit and Bloomberg.

### 3 Empirical patterns on Triparty

In this section, I present three facts of the Triparty market and discuss possible reasons that give rise to these empirical observations.

#### **Fact 1: MMFs simultaneously and consistently accept different repo rates from different dealers**

Against repo contracts that differ only in the identity of the dealer, MMFs simultaneously lend to multiple dealers and do so at consistently different rates.

To compare repo rates across dealers, I focus on a sub-sample of overnight repo contracts that are collateralized only by Treasury securities with a 2% haircut,<sup>16</sup> which retains 75% of all MMF-dealer-month observations.<sup>17</sup> Prior research has documented differences in repo rates between contracts backed by different collateral, even though the haircut on collateral theoretically adjusts for the quality of the underlying (Weymuller (2013)). I therefore compare repo rates only across repos that are backed by the same collateral. This is not restrictive because Triparty repo differentiates collateral not by

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<sup>16</sup>I restrict the sample to contracts with collateral to principal ratio of  $102\% \pm 0.1\%$ .

<sup>17</sup>From the total of 14,571 MMF-dealer-month observations, focusing on transactions that use Treasury as collateral leaves the sample with 11,486 observations, restricting the haircut to 2% leaves the sample with 10,938 observations.

CUSIP but by asset class. By focusing my analysis of repo rates on Treasury-backed overnight repo contracts that all have 2% of haircut, I retain a sizeable sub-sample where the repo rate is free from impact due to duration, collateral, and haircut, leaving dealer identity the only other factor that differentiates repo.

In this sub-sample of homogeneous repos, MMFs are seen to simultaneously accept different repo rates from different dealers. Figure 1 plots, as an example, the repo rate BlackRock received from lending to Goldman Sachs and Wells Fargo in 2016 and 2017.<sup>18</sup> We see that although Goldman Sachs and Wells Fargo consistently borrowed at different rates, BlackRock nonetheless lent to both borrowers month after month.

This observation is surprising because the difference in repo rates cannot be due to differences in the contractual terms of the repo. Moreover, although creditworthiness of borrowers can often be a source of price dispersion, especially on OTC markets, in 2016 and 2017, the short-term (6M) CDS rates of Goldman Sachs is on average 12 bps above that of Wells Fargo. This observation is all the more surprising in light of the fact that the same three agents transacted every month. It is unlikely that BlackRock was not aware of the systematically different rates paid by Goldman Sachs vs. Wells Fargo. Informational friction cannot explain such persistent difference.

More generally, MMFs in my sample on average lend to 10 dealers at a time, and the difference between the highest and the lowest rate *simultaneously* accepted by MMFs is on average 4 bps. This dispersion is, again, present in the context of repeated interaction. Indeed, the AR(1) persistence of whether a MMF-dealer pair trades is 85% ( $R^2 = 0.72$ ).

Between sophisticated financial institutions who repeatedly interact with each other,

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<sup>18</sup>To remove the effect of general interest rate trends, I re-state the transacted repo rate as the deviation to the volume-weighted median on that day. The choice of using the volume-weighted median as the centroid both conforms to the convention in the repo market and minimizes the impact of outliers. All published repo-based indices are calculated as the volume-weighted median, examples include the Secured Overnight Financing Rate (SOFR), the Triparty repo index, and the DTCC GCF repo index.

repos that differ only in the identity of the dealer trade at persistently different rate. Observing this, it is natural to wonder, what is the pattern in the Triparty rate dispersion, and what is the pattern in MMFs' lending?

## **Fact 2: Dealer identity drives repo rate dispersion**

The dispersion in apparently homogeneous repo contracts is driven by dealer identities. Continue using the overnight Treasury repo sub-sample, I show that dealer identities explain the preponderance of the repo rate variation both in the cross-section and in the time-series.

In Figure 2, I examine the dispersion of repo rates in the cross-section by regressing repo rates in each month on MMF or dealer fixed effects.<sup>19</sup> The plotted  $R^2$  from these regressions show that dealer identities alone explain about 50% of the variation, while MMF identities explain much less. In fact, even if MMF identities didn't matter for dispersion, we would expect MMF fixed effects to have some explanatory power as long as the sorting of dealer to MMF is not completely symmetric. I thus regress repo rates in each month on both the dealer and the MMF fixed effects. Once dealer identities are controlled for, adding MMF fixed effects does not improve the  $R^2$  by much. I formally test whether the additional MMF fixed effects are jointly 0, and I cannot reject the null at the 10% significance level in 72 of the 84 months.<sup>20</sup>

Repo rate dispersion is mostly driven by between-dealer variations; moreover, within a dealer, variations cannot be explained by MMF or MMF-dealer pair characteristics. In Table 1, I test the following characteristics: the amount of Treasury-backed overnight repo lending between a MMF-dealer pair (*Pair Treasury repo volume*), the share – or im-

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<sup>19</sup>To avoid fitting fixed effects over 1 or 2 data points, observations where a borrower or a lender has fewer than 3 transactions in a month are excluded, leaving the sample with 10,453 observations.

<sup>20</sup>Multiple hypothesis testing is corrected using [Holm \(1979\)](#).



portance – of this pair’s lending volume to the MMF’s overall Treasury-backed overnight repo lending (*Pair vol as percent of MMF*), the share of this pair’s lending volume to the dealer’s overall Treasury-backed overnight repo borrowing (*Pair vol as percent of borrower*), the MMF’s total Treasury-backed overnight repo lending (*MMF total Treasury repo vol*), and the number of dealers to whom the MMF lends (*MMF number of counterparty*). None of these characteristics offers a statistically significant explanation to the rate dispersion, judging by either the individual coefficient’s statistical significance or the improvement in  $R^2$  from including these regressors (difference between  $R^2$  (proj model) and  $R^2$  (full model)). Putting together the results from Figure 2 and Table 1, we see that while different dealers systematically pay different rates for repo funding, different MMFs lending to the same dealer do not receive statistically different rates.

Dealer identity is a key driver of repo rate variations in not only the cross-section but also the time series. Given the OTC nature of repo transactions, prior studies such as Han and Nikolaou (2016) focus on differences among MMF-dealer-pairs to explain rate variations. In Table 2, I compare the goodness of fit between models that include only dealer fixed effects and models that include pair fixed effects. Comparing Models (1) versus (2), it is true that including all the pair fixed effects improves  $R^2$  by about 0.07, yet this is achieved with 251 more regressors. Therefore, the Akaike information criteria (AIC) ranks these two models similarly, and the Bayesian information criteria (BIC) prefers the more parsimonious model with only dealer fixed effects. The same pattern holds when comparing Models (3) versus (4), where year fixed effects are also added. In short, dealer identities are of first-order importance in explaining Triparty repo rate dispersion.

### **Fact 3: Larger MMFs connect to more dealers to spread out lending**

MMFs construct their overnight cash portfolio in a systematic and size-dependent way: as MMFs get larger, they lend to more dealers so as to spread out their lending, giving smaller shares of their portfolio to each dealer.

This pattern is illustrated in Figure 3, where a snapshot of the repo lending done on October 31, 2016 by the larger BlackRock MMF is drawn next to that by the smaller Legg Mason MMF. The larger BlackRock not only lent to more dealers but also lent smaller shares of its portfolio to each dealer. Shown more systematically in Table 3, this relationship between the portfolio size and the extensive and the intensive margin of the portfolio holds across MMFs.

To start, in Model (1), we see that the number of dealers to whom MMFs lend increases by about 3 as the size of MMFs' overnight cash portfolio doubles.<sup>21</sup> This is perhaps intuitive. There are fixed costs such as setting up Master Repurchase Agreements<sup>22</sup> before an MMF can lend to a dealer, and larger MMFs can afford establishing lending relationships with more dealers. But why do MMFs want to lend to more dealers?

MMFs are not establishing more lending relationships to better “rate shop”. If MMFs willingly incur fixed costs because lending to more dealers allows MMFs to better discover attractive rates, then we would expect the portfolios of more connected MMFs to undergo more frequent and significant changes.<sup>23</sup> Yet as shown in Figure 4, more connected MMFs maintain portfolios that are just as stable – if not more stable over time. I measure the

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<sup>21</sup>Overnight cash portfolio is measured as the sum of all overnight repo lending, inclusive of repo placed in RRP, see Section 5.2 for details on RRP.

<sup>22</sup>Master Repurchase Agreements (MRAs) typically set out the protocol for margin maintenance and in the event of default; thus, day-to-day, cash-lenders and cash-borrowers only need to decide on the repo rate and volume.

<sup>23</sup>From Fact 2, we know that having more connections does not grant an MMF preferential pricing vis-à-vis any one dealer. Hence, the price-related advantage to forming more connections is likely the ability to shift lending to whichever dealer offers the best rate on a given day.

similarity between MMFs’ overnight repo portfolios across time using cosine similarity:

$$\text{CosSim}(\mathbf{x}, \mathbf{y}) = \frac{\mathbf{x} \cdot \mathbf{y}}{\|\mathbf{x}\| \|\mathbf{y}\|},$$

where  $\mathbf{x}$  and  $\mathbf{y}$  denote a given MMF’s portfolio at time  $t$  and  $t + n$ , respectively. The closer the cosine similarity is to 1, the more stable the portfolio.

In Panel A of Figure 4, we see that, irrespective of the number of dealers MMFs lend to at time  $t$ , MMFs maintain very similar portfolios at time  $t + 1$ . In fact, for portfolios that start with 10 or more dealers, the mean cosine similarity is about 0.9, slightly higher than the 0.8 mean of portfolios that start with fewer than 10 dealers. In Panel B of Figure 4, we see that the stability in portfolios is not a quirk of short-term stickiness, but that portfolios at time  $t$  and time  $t + 6$  also exhibit high degrees of similarities across MMFs.

MMFs connect to more dealers to lend smaller shares of the portfolio to each dealer, thus spreading out the portfolio. In Model (2) of Table 3, we see that as MMFs double in size, the median portfolio share lent to dealers decreases by 6.7% on average. Unlike the mean share of the portfolio, the median share of the portfolio need not change as the number of dealers in the portfolio changes. Rather, this declining median share is a harbinger that as MMFs increase in size, they reduce, across the distribution, the share lent to any one dealer. Indeed, in Models (3) and (4), we see that the maximum share and the minimum share also decrease, and by similar magnitude, as MMFs increase in size.

## Discussion of empirical patterns

Facing dealers that borrow at different repo rates (Fact 2), MMFs lend to multiple dealers simultaneously (Fact 1), and show a size-dependent tendency to spread out their portfolios (Fact 3). These facts about the Triparty market suggest at least two economic forces that work in tandem.

First, MMFs accepting knowingly different rates indicates that dealers' identities differentiate repo lending in a way that rationalizes differences in pecuniary returns. What is different between dealers that is so valued by MMFs? Interviews with over a dozen industry participants suggest that this difference lies in how reliable a dealer is to use her scarce balance sheet to take repo loans from MMFs. MMFs have a strong preference for stable repo investments to minimize any operational disruptions. Dealers, however, may not be able to consistently borrow because repo is balance-sheet intensive and thus can come with a high opportunity cost. MMFs therefore likely favor those dealers who choose to consistently devote their balance sheet to repo intermediation. I check this hypothesis in Section 5.5, and find that estimated preferences for dealers indeed exhibit strong correlations with measures of borrowing reliability. The presence of this preference makes lenders perceive lending to different dealers as differentiated investment opportunities that warrant differential rates.

At the same time, it is noteworthy that MMFs lend to multiple dealers simultaneously. It is as if MMFs have an aversion to concentration and purposely spread out their lending.<sup>24</sup> At first blush, this sounds perplexing, for Triparty repo carries little credit risk,<sup>25</sup> so why would MMFs want to diversify their repo investments? MMFs may want to limit their dollar exposure to any one dealer to minimize operational risks. Tail risks such as cyber attacks could prevent a dealer from returning her repo loan on time. If MMFs take possession of the posted collateral, MMFs would have to immediately liquidate the collateral.<sup>26</sup> Fire sales could materially compromise the value of the collateral if

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<sup>24</sup>There are regulated counterparty caps on certain assets that MMFs own, e.g. commercial paper. However, such caps do not apply to repo because repo is treated as a “look-through” asset so it’s as if MMFs are holding the underlying Treasury collateral, which bears no cap.

<sup>25</sup>Triparty repo are largely overnight, over 90% is collateralized by high quality collateral such as Treasury or Agency MBS with haircuts that have been shown to be conservative (Hu et al. (2017)), and the collateral is bankruptcy remote. For these reasons, even during the depth of the Great Financial Crisis, there was no run or default on Triaprtty (Krishnamurthy et al. (2014)).

<sup>26</sup>Regulations limit the tenor of securities held by MMFs to 397 days. As securities posted as repo

the total amount to be sold is large. Worries over fire sale may be the reason why MMFs seem to have a dollar cap on repo lending, leading to the observed portfolio diversification that intensifies with size. Although realizations of such operational risks have not been observed, concerns for them could still be powerful forces.

One manifestation of MMFs’ aversion to concentration is that on quarter-ends, when some dealers window dress and cut back on repo borrowing, MMFs do not shift their lending to the other dealers. As Table 4 shows, on quarter-ends, the 10 dealers governed by regulations in the European Union (EU) and the United Kingdom (UK) cut back on repo borrowing,<sup>27</sup> both in dollar terms (Models (1) and (2)) and in percentage measures (Models (3) and (4)). On average, an EU or UK dealer reduces her repo borrowing by about \$5 billion on quarter-ends, even after controlling for the average repo borrowing in a given quarter (Model (2)). Yet the repo borrowing by dealers in CA, JP, and US barely changes on quarter-ends. MMFs’ apparent reluctance to shift their lending to CA, JP, or US dealers is not because these dealers offer dramatically lower repo rates on quarter ends (Model (5)). Rather, MMFs’ behavior on quarter-ends corroborates with the notion that MMFs are averse to lending too much of the portfolio to any one dealer. The consequence of this aversion, coupled with MMFs’ tendency to lend to the same dealers over time, is that MMFs may not nimbly respond to rate changes because shifting volumes may push MMFs against their concentration limits. This, in effect, makes dealers monopsonies over the MMFs that lend to them. As differently sized MMFs exhibit different levels of aversion, dealers borrowing from different subsets of MMFs face supply curves of differing elasticity, providing another reason for seeing differential rates.

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collateral exceed this tenor requirement, they cannot be held by MMFs indefinitely.

<sup>27</sup>UK banks reported their balance sheet size as quarter-end snapshots through 2015. In the calendar year of 2016, UK banks reported month-end snapshots. Starting 2017, UK banks reported quarter-averages. UK banks’ quarter-end window-dressing activities diminished starting in 2016.

In short, differences in MMFs' value for dealer stability and in MMF's aversion to concentration could both contribute to the observed empirical patterns. To account for the effect of these forces in the equilibrium requires building and estimating a structural model of the Triparty market. Such a model must be disciplined by patterns in the data. A search model is unlikely to be a candidate, as the dispersion is observed in the context of repeated interactions between the same set of agents. A model that relies purely on linear utility from pecuniary returns is also likely insufficient, as the agent's optimal choice in a linear utility is to concentrate everything in a single best choice, which is at odds with the observed multiplicity of lending. The first-order importance of dealers' identities in explaining rate dispersion, and the striking simultaneity in MMFs' lending, therefore, lead me to develop a model that features lenders with possibly concave utilities responding to posted, borrower-specific pricing.

## 4 Model

I now develop a model for borrowing and lending overnight cash via repo on the Triparty market. The aim of the model is to capture the key economic forces that generate the striking patterns in the data. The purpose of the model is to describe Triparty's equilibrium so that the impact of monetary policy tools can be assessed through counterfactual analyses.

The model has two types of agents interacting in the supply and demand of repo funding. On the supply side, lenders, e.g. MMFs, allocate their overnight cash with possible aversion to portfolio concentration and non-pecuniary preferences for borrowers. On the demand side, borrowers, i.e. dealers, act as monopsonies and set the repo rates used to attract funding.

#### 4.1 Lender's problem

Let  $i$  index lenders and  $j$  borrowers. Lender  $i$  has a portfolio of investments with one-day maturity, and at each time  $t$ , he chooses the share of this overnight portfolio going to each of the  $J$  borrowers,  $x_{ijt}$ . The share of the portfolio not lent out,  $x_{izt}$ , goes to the lender's outside option: safe investments that mature overnight and for which the lender harbors no concentration aversion.<sup>28</sup>

$$U(\mathbf{x}_{it}; \omega, \alpha) = \max_{\mathbf{x}_{it}} \sum_{j=1}^J \frac{\omega_{ijt} R_{jt}}{\alpha_{it}} \{\exp(\alpha_{it} x_{ijt}) - 1\} + R_{zt} x_{izt},$$

$$\text{s.t. } \sum_{j=1}^J x_{ijt} + x_{izt} = 1, x_{i1t}, \dots, x_{iJt} \geq 0.$$

The lender's utility is quasi-linear; linear in his portfolio allocation to the outside option, which earns a gross return of  $R_{zt}$ . His utility from lending to one of the  $J$  borrowers is possibly concave in the share lent, with the degree of the curvature controlled by an aversion to concentration parameter,  $\alpha_{it} \leq 0$ . The utility from lending to a borrower further depends on the gross return,  $R_{jt}$ , set by the borrower and taken as given by the lender, and the lender's non-pecuniary preference for that borrower,  $\omega_{ijt} \geq 0$ .

From the lender's FOC, the optimal share of portfolio lent to borrower  $j$  is:

$$x_{ijt}^* = \frac{\log(R_{jt}) + \log(\omega_{ijt}) - \log(R_{zt})}{-\alpha_{it}}. \quad (1)$$

The optimal share increases in the attractiveness of borrower  $j$  relative to the outside option ( $R_{zt}$ ),<sup>29</sup> where borrower  $j$ 's attractiveness is a function of the repo rate she pays

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<sup>28</sup>Examples of the lender's outside option include the RRP and Treasury bills. See Section 5.2.

<sup>29</sup>The FOC emphasizes the trade-off between returns from borrower  $j$  and the outside option, and assumes the between-borrower cross-elasticity to be 0. This modeling assumption is supported by the minimal substitution between borrowers observed on quarter-ends, when a subset of borrowers experience

$(R_{jt})$  and the non-pecuniary preference she garners  $(\omega_{ijt})$ . At a given  $R_{jt}, R_{zt}$ , and  $\omega_{ijt}$ , different lenders will allocate different shares based on their concentration aversion  $(\alpha_{it})$ .

The concentration aversion,  $\alpha_{it}$ , controls how quickly the lender's utility diminishes when lending to a given borrower. It therefore determines how distributed lender  $i$ 's portfolio is and how  $i$ 's reacts to repo rate changes. Consider the extreme case of  $\alpha_{it} \rightarrow 0$ : lender  $i$ 's utility becomes linear, and he would concentrate all of his lending into one single best repo investment. As  $\alpha_{it}$  becomes more negative, the utility becomes more concave, and that compels the lender to spread out his lending, leading to concurrent lending to multiple borrowers and reflecting an aversion to concentration. Intuitively, if the lender is averse to lending too much to any one borrower, then when one of the borrowers raises her rate, the lender will not consolidate his lending to take advantage of this rate increase. The concentration aversion parameter,  $\alpha_{it}$ , is thus intimately tied to lender's semi-elasticity. We can see this by differentiating the lender's first-order condition (Equation 1) with respect to the log of repo rate. The optimal response in share to (percent) rate change is exactly  $\frac{\partial x_{ijt}^*}{\partial \log(R_{jt})} = -\frac{1}{\alpha_{it}}$ . That is, if a borrower doubles the repo rate she offers, the lender who is lending to her would increase his lending by  $-\frac{1}{\alpha_{it}}$  of his portfolio.

As documented in Fact 3, there is an empirical relationship between a lender's portfolio size and his aversion to concentration, I therefore parameterize  $\alpha_{it}$  as

$$\alpha_{it} = \beta_0 + \beta_1 \cdot \sqrt{y_{it}},$$

where  $y_{it}$  is the size of lender's overnight cash portfolio. I take  $y_{it}$  as exogenous, as the overnight cash portfolio serves to meet an MMF's liquidity needs and tends to be a stable fraction of the MMF's overall AUM.

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funding shocks. See *Discussion of empirical patterns* in Section 3.



The attractiveness of lending to a borrower depends on lender's preference  $\omega_{ijt}$ . This preference affects to whom and by how much  $i$  lends. The marginal utility of lending the first dollar to borrower  $j$  is  $\frac{\partial U}{\partial x_{ijt}} \Big|_{x=0} = \omega_{ijt} R_{jt}$ . Given that the lender's cash could otherwise earn a return of  $R_{zt}$ , lending to  $j$  occurs if and only if  $\omega_{ijt} R_{jt} > R_{zt}$ . Therefore,  $\omega_{ijt}$  differentiates borrowers and determines to whom the lender starts lending. Moreover, because the utility from lending depends on an  $\omega_{ijt}$ -scaled  $R_{jt}$ , differences in  $\omega_{ijt}$  govern how much different borrowers can get from the same lender. I parameterize  $\omega_{ijt}$  as

$$\omega_{ijt} = \chi_{ijt} \cdot (\nu_{ijt} + \epsilon_{jt}); \quad (2)$$

$$\chi_{ijt} \sim \text{Bernoulli}(\text{Logistic}(\rho_{ij} + \delta \log(y_{it}))),$$

$$\nu_{ijt} \sim 1 + \text{Gamma}(\text{shape} = k, \text{scale} = \psi_j/k),$$

$$\epsilon_{jt} \sim \text{LogNormal}\left(\frac{-\sigma^2}{2}, \sigma^2\right).$$

$\chi_{ijt}$  is a binary random variable that determines whether lender  $i$  has a nonzero preference for borrower  $j$ . Its realization depends on borrower-lender pair-specific parameters,  $\rho_{ij}$ . This parameterization is motivated by the high persistence in trading, and is necessitated by the fact that trading relationships on Triparty have been established long before my sample began.  $\chi_{ijt}$  further depends on the size of the lender's overnight cash portfolio,  $y_{it}$ , through  $\delta$ . This allows for larger lenders to lend to more borrowers.

If the lender has a nonzero preference for a borrower, then  $\nu_{ijt}$  is drawn from a Gamma distribution<sup>30</sup> whose mean depends on borrower-specific  $\psi_j$ . Thus, in reduced-form,  $\psi_j$  captures the systematic variations in  $\omega_{ijt}$ , conditional on lending. Perceiving a high non-pecuniary preference could prompt the lender to either lend at a lower rate or lend more

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<sup>30</sup>The choice of Gamma ensures positive preferences and gives flexibility in fitting the data. If the *shape* parameter,  $k$  is large, the Gamma distribution approximates Normal; if  $k$  is small, then the Gamma distribution approximates Exponential.

at a given rate. I speculate that variations in  $\psi_j$  are driven in part by a preference for reliable borrowing. This interpretation is supported in Table 8, which shows a correlation between the  $\psi_j$  parameters I recover and measures of borrower reliability (see Section 5.5 for more discussion).

Finally, the model explicitly accounts for possible borrower-time specific shocks to the lender’s preference, which are known to market participants but not the econometrician. These “supply shocks”,  $\epsilon_{jt}$ , if present, threaten the OLS identification of the relationship between rate and volume, because these shocks affect the observed lending volume without having observable proxies that one can use to control for their effect.

## 4.2 Borrower’s problem

At each  $t$ , borrower  $j$  maximizes her profit by choosing the gross repo rate  $R_{jt}$  that she pays to all lenders for repo funding:

$$\max_{R_{jt}} [S_{jt}(Q_{jt}) - R_{jt}] \cdot Q_{jt}(R_{jt}),$$

where  $Q_{jt}(R_{jt}) = \sum_i [\mathbf{E}[x_{ijt}(R_{jt})] \cdot y_{it}]$  is the total quantity of funds borrower  $j$  expects to obtain at rate  $R_{jt}$ , and  $S_{jt}(Q_{jt})$  is the average value of intermediating funds at  $Q_{jt}$ .

Triparty borrowers demand repo funds because these funds can be intermediated to generate value. For example, the funds could be lent out (via repo again) to a borrower’s clients, such as hedge funds that don’t have direct access to the Triparty market but nevertheless need repo funding to finance security holdings. Alternatively, the funds could be used to finance a borrower’s own security holdings, such as those purchased during a Treasury security auction. The value that a borrower attaches to her repo funding could depend on the total amount of funds that she obtains. Importantly, the

value modeled here reflects the pure economic benefit accruing to the borrower and is thus *net* of regulatory costs such as balance-sheet cost. Regulatory costs are important in the determination of asset prices, see [Du et al. \(2020\)](#), [Duffie and Krishnamurthy \(2016\)](#). The full cost for a borrower’s clients to use repo funds would be the sum of the value of funds, as modeled here, and any applicable regulatory cost.

Differentiating the borrower’s problem with respect to repo rate, the first-order condition yields that borrower  $j$ ’s optimal repo rate is:

$$R_{jt}^* = \underbrace{S'_{jt} \cdot Q_{jt} + S_{jt}}_{\text{marginal benefit from intermediation at } Q} - \underbrace{\frac{Q_{jt}}{Q'_{jt}}}_{\text{markdown}} \quad (3)$$

The optimal rate offered by the borrower embeds a markdown from her marginal benefit from intermediation. The magnitude of the markdown is therefore a measure of borrower’s market power. This markdown is a direct function of lenders’ supply of funds to the borrower,  $Q_{jt}(R_{jt})$ . At a given quantity,  $Q_{jt}$ , if the supply is highly responsive to rate changes, then  $Q'_{jt}$  would be large and the markdown would be small. Conversely, the borrower can set a large markdown if the lenders’ response to her repo rate changes is small. The ability to set markdown – or the extent of borrower’s market power – therefore depends on the lenders’ concentration aversion ( $\alpha_{it}$ ) and preference ( $\psi_j$ , capturing  $\omega_{ijt}$ ).

## 5 Estimation

I estimate the lender’s problem to separately quantify the two key parameters  $\alpha_{it}$  and  $\psi_j$  (capturing  $\omega_{ijt}$ ). I first discuss sources of variation, measurement of  $R_{zt}$ , and the instrumental variable I employ to achieve identification. I then outline the indirect inference estimation approach that I use. Finally, I present estimated parameters and the implied

borrower's markdown.

## 5.1 Sources of variation

From the lender's FOC (Equation 1), we know that both  $\alpha_{it}$  and  $\omega_{ijt}$  can affect how much lender  $i$  lends to borrower  $j$  ( $x_{ijt}$ ) at a given repo rate ( $R_{jt}$ ). Yet it is possible to separate their effects because  $\alpha_{it}$  captures differences across lenders and  $\omega_{ijt}$  captures differences across borrowers.

Since  $\alpha_{it}$  varies by  $i$ , comparing lending to the same borrower by different lenders can inform us about the relative magnitude of  $\alpha_{it}$ . Similarly, as  $\psi_j$  captures the systematic variation in  $\omega_{ijt}$  and it varies by borrower, comparing lending received by two different borrowers from the same set of lenders can inform us about the relative magnitude of  $\psi_j$ .

However, cross-sectional comparisons cannot pin down the level of these parameters. To do so, I appeal to the direct relationship between  $\alpha_{it}$  and lenders' semi-elasticity. As discussed in Section 4.1, the portfolio allocation response of each lender  $i$  to borrower  $j$ 's repo rate change depends on their individual  $\alpha_{it}$ . When borrower  $j$  is setting her repo rate, the supply schedule facing her is a function of all the individual  $\alpha_{it}$  associated with those lenders that lend to her. Estimating the supply semi-elasticity faced by borrowers will therefore inform the average level of  $\alpha_{it}$ , which in turn informs the levels of  $\psi_j$ .

From estimated  $\alpha_{it}$  and  $\psi_j$ , we can calculate borrowers' markdown. Borrowers' unobserved marginal benefit from intermediation, according to Equation 3, will then be the sum of the estimated markdown and the observed borrower repo rates.

## 5.2 Measuring $R_{zt}$ , lender's outside option

In lender's FOC (Equation 1), the lending decision directly depends on the comparison between a borrower's offered repo rate ( $R_{jt}$ ) and the return on lender's outside option

( $R_{zt}$ ). I will measure  $R_{zt}$  as the higher of the RRP rate or the 1-day Treasury bill yield.

The lender's outside option is a safe, overnight investment, for which the lender harbors no concentration aversion. Placing repo with the Federal Reserve through the RRP fulfills these functions, making  $R_{RRP,t}$  a credible outside option to lending to repo borrowers. Another measure of the outside option is the 1-day Treasury bill yield. MMFs can invest in Treasury securities that have a maturity of less than one year. Buying Treasury securities is also investing with the U.S. government and thus bears similar attributes to lending to the RRP. However, there is no reported overnight Treasury yield. I thus impute a 1-day Treasury yield by adjusting for the term-structure using the 1-day and the 1-month OIS.

I generate the time series of  $R_{zt}$  as 1-day Treasury bill yield before September 2013, when the RRP was introduced, and the RRP rate thereafter; the RRP rate is always higher than the 1-day Treasury bill yield in my sample. In the data, the correlation between the 1-day Treasury bill yield and the median Triparty repo rate is 0.78 before the introduction of the RRP and 0.13 thereafter, supporting my choice of  $R_{zt}$ .

The introduction of the RRP cuts the sample that I use in the estimation into two sub-periods. The Pre period covers January 2011 through August 2013, and the Post period goes from October 2014 through November 2017. I purposely leave out the September 2013 to September 2014 period, as the RRP was in testing and had a constraining counterparty cap, making it difficult to ascertain the true marginal outside option for lenders. In my estimation, I also exclude all quarter-end months because many regulations are enforced only on quarter-ends. Numerous studies have focused on quarter-ends to study the distortion regulations have on markets (Du et al. (2018), Wallen (2020)). My study aims to reveal the extent of imperfect competition even outside of quarter-ends. The final

estimation sample therefore consists of 48 month ends from 2011 through 2017.

### 5.3 Instrumental variable

Finding the supply semi-elasticity is key to estimating my model parameters. However, the OLS relationship between rate and volume may be biased due to preference shocks that are unobserved by the econometrician ( $\epsilon_{jt}$  in Equation 2). For example, if there are negative preference shocks, a borrower will be seen to offer a high repo rate but attracting only a modest amount of funds, biasing the true relationship to 0.

I estimate the Triparty market supply semi-elasticity using an instrumental variable that shocks the borrowers' funding needs. The U.S. Treasury department periodically auctions marketable debt securities of various maturities. Dealers bid, make markets, and take speculative positions around Treasury auctions (Fleming and Rosenberg (2008)), and they typically finance their Treasury holding with repo. Therefore, the amount of Treasury auctioned likely correlates with how much borrowers want to borrow. Using Treasury auctions as an instrument, I can find by how much borrowers need to raise their repo rates to attract additional funding.

Specifically, I construct the instrument as the amount of *non-bill* Treasury securities *offered* to be auctioned such that they *settle* on the same days as MMFs' reporting dates. On these *settlement* dates, titles transfer and dealers must finance their acquisitions. Repo volumes on settlement days are therefore mostly directly impacted by Treasury auctions. To avoid potential endogeneity between repo rates and how much dealers decide to purchase, I focus on the amount of Treasury securities *offered* for sale, which likely reflects the Treasury department's fiscal needs and is plausibly exogenous to borrower-specific preference shocks.<sup>31</sup> Finally, I include only auctions of Treasury securities with

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<sup>31</sup>As discussed below, time fixed-effects are included to absorb macroeconomic shocks, narrowing the

maturities of one year or more. *Non-bill* securities cannot be purchased by MMF, auctions of these securities thus do not change the trade-offs facing the lenders.<sup>32</sup>

Table 5 summarizes the instrument-induced inverse semi-elasticity. All regressions in the table are run at the borrower-time level, as borrowers set borrower-time specific repo rates. Because identification relies on shocks that impact borrowers at each point in time, standard errors are clustered by time (month).

Models (1) and (2) show the first-stage impact of Treasury auction offers on repo volume from:  $Vol_{jt} = \beta_{1st}TreasuryOffer_t + BorrowerFE + YearFE + e_{1st,jt}$ . Model (1) shows that in the estimation sample period of January 2011-August 2013 and October 2014-November 2017, there is a strong correlation between the amount of Treasury securities offered in auctions and the amount of Triparty repo funding obtained by borrowers. As there may be macroeconomic shocks that affect both the Triparty repo market and the Treasury department’s decision to issue debt, I add year fixed effects in Model (2). In other words, my instrument relies on auction variations within the calendar year, which typically reflects tax revenue fluctuations.<sup>33</sup> The magnitude of the volume response reduces from 46.8 to 16.3, but are still significant at the 5% level. As I measure Treasury auction offers in trillions of dollars, the estimated coefficient imply that a \$40 billion, or 1 standard deviation, increase in the amount offered in Treasury auction is associated with an average increase of \$0.65 billion in a borrower’s repo funding.

Model (3) shows the repo rate response to instrumented volume change from:  $\log(R_{jt}) -$

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threat to identification to shocks that are unique to borrower-time and simultaneously affecting Treasury’s auction offers.

<sup>32</sup>In unreported robustness checks, I confirm that the amount of non-bills offered in Treasury auctions is not significantly correlated with either the level or the volatility of MMF AUM flows.

<sup>33</sup>The year fixed effects are, specifically, indicator variables for each of 2011, 2012, 2015, 2016, 2017, and one indicator variable for the first 6 non-QE months in 2013 and the last 2 non-QE months in 2014. The two calendar months included in 2014 are the two calendar months missing in 2013, which completes the fiscal year. Robustness checks using separate fixed effect for 2013 and 2014 show similar results that are more noisily estimated.

$\log(R_{zt}) = \beta^{IV} \widehat{Vol}_{jt} + BorrowerFE + YearFE + e_{IV,jt}$ .<sup>34</sup> The estimated coefficient shows that to raise \$1 billion more in repo funding, a borrower needs to raise her repo rate by 1.57 bps. In other words, a 1 bp increase in repo rate is associated with a \$0.64 billion increase in a borrower's funding. For the average borrower, this is about 3.6% of her funding. This estimate compares to recent events in the Triparty market. When the Fed unexpectedly raised the RRP rate by 5 bps on June 17, 2021, the RRP saw an overnight inflow of \$225 billion from a base of \$1628 billion Treasury-backed Triparty repo,<sup>35</sup> implying a semi-elasticity of 2.9% per 1 bp change. At the same time, this estimate is higher than comparable estimates for the Treasury bill market in Greenwood et al. (2015),<sup>36</sup> Duffee (1996),<sup>37</sup> and Bernanke et al. (2004),<sup>38</sup> suggesting that the supply on Triparty is more inelastic.

The first-stage specification in Model (2) features a market-wide instrument that applies to all Triparty borrowers,  $TreasuryOffer_t$ . The IV estimate in Model (3) is therefore the average rate response to the average induced volume. Borrowers may have heterogeneous volume response to Treasury auction offers. If I knew the borrower-specific participation rate in Treasury auctions, I could refine my instrument to be individual shocks that are the product of Treasury auction offer and individual auction participation. This data is not publicly available. In Models (4) and (5), I run a version of this

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<sup>34</sup>I obtain borrower-time specific repo rates ( $R_{jt}$ ) by volume-weighting the observed borrower-lender pair repo rates for Treasury-backed repo with 2% haircut.

<sup>35</sup>The closest public release of the size of the Triparty market is as of June 9, 2021: <https://www.newyorkfed.org/data-and-statistics/data-visualization/tri-party-repo>.

<sup>36</sup>Greenwood et al. (2015) estimates, using instrumental variable on sample from 1983 to 2007, that a 1 percentage point decrease in  $\frac{\Delta Treasury}{GDP}$  leads to 38.6 bps decrease in the two-week Treasury yield. The average annual GDP between 2011 and 2017 is \$18.7T. This implies that \$1b increase in the supply of Treasury increases the yield by 0.21 bps.

<sup>37</sup>Duffee (1996) estimates, using data on each January from 1983 to 1994, that 1% increase in 1-month Treasury bill outstanding increases yield by 1.012 bps. The average Treasury bill outstanding over the sample period is \$1.6 trillion, of which roughly 30% is due within a month. This implies that, again, a \$1b increase in 1-month Treasury bill outstanding increases the yield by 0.21 bps.

<sup>38</sup>Bernanke et al. (2004) estimates using Japanese purchase of Treasury securities that a \$1b reduction in Treasury outstanding decreases the yield on 3-month Treasury by 0.18 bps and on 2-year Treasury by 0.55 bps.



heterogeneous-response IV by using borrowers' average repo share as a proxy for their auction participation. Specifically, I calculate each borrower's share in the overall Tri-party repo volume at each point in time, and take the time series average to arrive at a time-invariant borrower share. The assumption behind using the product of Treasury auction offer and borrower repo share as an instrument is two-fold. First, borrowers that are more active in repo would also respond more in Treasury auction. Second, since this share is time-invariant, it is not correlated with errors in the IV regression. The estimated inverse semi-elasticity from Model (5) is very similar in magnitude to the estimate in Model (3).

The precision of the instrumental variable estimation depends on the strength of the instrument. The cluster-robust effective F-stat of the instrument in Model (2) is 5.8, below the rule-of-the-thumb threshold of 10. To better understand the implication of using a possibly weak instrument on the IV inference in Model (3), I compute the Anderson-Rubin confidence interval. The Anderson-Rubin confidence interval has the correct coverage regardless of the strength of the instrument and is efficient in just-identified models with a single instrument ([Andrews et al. \(2019\)](#)), as is the case here. The 95% Anderson-Rubin confidence interval for this estimation is (0.5, 8.6), see Appendix Figure [A2](#). This interval is bounded away from the imprecise and near-zero OLS estimate in Model (6), suggesting that the instrument is useful. At the same time, this interval is very wide in the other direction. In other words, there is reasonable confidence that the instrumented semi-elasticity is not zero, however, I am much less certain that the true value is not larger. A larger estimate would mean that borrowers need to raise their rates even more in order to induce additional volume, implying an even more inelastic supply.

## 5.4 Estimation approach

I estimate the parameters of the lender's model using a mixture of indirect inference (Gourieroux et al. (1993)) and maximum likelihood.

Applying indirect inference, I choose parameters such that the data simulated by these parameters would generate moments matching those generated from the original data. The moments that I include summarize the distinct data patterns discussed so far. First, as the size-dependent concentration aversion parameter,  $\alpha_{it}$ , controls lender's response to rate change, my moments include the IV coefficient on  $\widehat{Vol}_{jt}$  from Model (3) of Table 5. This coefficient is a direct function of  $\alpha_{it}$ :  $\beta_{IV} = \frac{1}{T} \frac{1}{J} \sum_{t \in T} \sum_{j \in J} \left( \sum_{i \in x_{ijt} > 0} \frac{y_{it}}{\alpha_{it}} \right)^{-1}$ , and can inform the average level of  $\alpha_{it}$ . The parameter  $\beta_1$  in  $\alpha_{it}$  governs the dependence of  $\alpha_{it}$  on lender's portfolio size. I therefore include as a moment the coefficient from regressing lender's median portfolio share on portfolio size (Model (2) of Table 3). Next, as  $\psi_j$  in  $\omega_{ijt}$  reflects borrower-specific influences on portfolio allocation, I include as moments each borrower's conditional average lender share and unconditional average probability to borrow.<sup>39</sup> Finally, as  $\sigma^2$  and  $k$  (*shape*) determine the variance of  $\epsilon_{jt}$  and  $\nu_{ijt}$ , respectively, they determine how much variation in the observed data can be explained by the included model parameters. I use the  $R^2$  from regressing portfolio shares on lender portfolio size and borrower fixed effects,<sup>40</sup> and on lender portfolio size and borrower-time fixed effects<sup>41</sup> to learn about these two parameters.

The  $\chi_{ijt}$  in  $\omega_{ijt}$  controls whether a borrower receives funds. I recover the parameters

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<sup>39</sup>Unconditional probabilities are necessary to inform  $\psi$  because there are observations where borrower's repo rate ( $R_{jt}$ ) is less than the return on the outside option ( $R_{zt}$ ). To rationalize these observations, not only would  $\chi_{ijt}$  need to take on the value of 1 (as opposed to 0) but  $\psi_j$  also needs to be sufficiently large.

<sup>40</sup> $x_{ijt} = b_{1,\sigma} \log(y_{it}) + BorrowerFE + e_{\sigma,ijt}$ , where  $\log(y_{it})$  absorbs the effect from  $\alpha_{it}$  and  $BorrowerFE$  absorbs the effect from  $\psi_j$

<sup>41</sup> $x_{ijt} = b_{1,k} \log(y_{it}) + BorrowerMonthFE + e_{k,ijt}$ , where  $\log(y_{it})$  absorbs the effect from  $\alpha_{it}$  and  $BorrowerMonthFE$  absorbs the effect from  $\psi_j$  and  $\epsilon_{jt}$

of  $\chi_{ijt}$  by maximizing the proportion of correctly predicted lending occurrence between each pair at each time. Given the logistic transformation of underlying parameters, the estimation of pair-specific  $\rho_{ij}$  poses a potential incidental parameter problem. I apply the analytical bias correction as suggested by [Hahn and Newey \(2004\)](#) to specifically address this concern. The difference between the bias corrected estimates and the simple maximum likelihood estimates are small because the sample period is moderately large ( $T = 48$  for most pairs).

The parameters of my model are over-identified. I weigh the moments using the inverse of the variance-covariance matrix for moment conditions calculated in bootstrapped samples. The bootstrapped samples are bootstrapped in blocks of time (month) clusters, in accordance with the IV regression.

## 5.5 Results and discussions

The model parameters estimated using indirect inference are summarized in [Table 6](#), along with their time-clustered block-bootstrapped confidence intervals. The maximum likelihood estimate of  $\delta$  is separately reported in [Table 7](#).<sup>42</sup>

### **Lender's concentration aversion: $\alpha_{it}$**

The estimated  $\beta_0$  and  $\beta_1$  are used to calculate  $\alpha_{it}$ , which has a mean of -0.034 and an interquartile range of (-0.025, -0.043). Because the possible support of  $\alpha_{it}$  is  $[-\infty, 0)$ , the fact that  $\alpha_{it}$  is clearly bounded away from 0 shows that lenders do exhibit an aversion to portfolio concentration, even if that aversion is not prohibitively strong. Based on calculated  $\alpha_{it}$ , borrowers on average need to raise repo rates by 24 bps to double funding

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<sup>42</sup>Pair-specific  $\rho_{ij}$  and the comparison between data and simulated moments are omitted for brevity and are available upon request.

attracted. Importantly,  $\beta_1$ , the size dependency of concentration aversion, is estimated to be negative. This coheres with the empirical pattern that larger funds puts smaller shares of portfolio into each borrower. This also intimates that policies that change the size of lenders could affect competition through  $\alpha_{it}$ ; I explore this point by examining the impact of the 2016 Money Market Fund Reform in Section 6.3.

Armed with estimated  $\alpha_{it}$ , it is now possible to examine the elasticity facing each individual borrower. Appendix Table A1 shows that if borrowers were to raise their repo rates by 1 basis point, they would increase their funding between 1.7% and 8.3%. There is evidently substantial heterogeneity in the Triparty market, a phenomenon that would be difficult to discern from the market-level semi-elasticity implied in the IV. Interestingly, Goldman Sachs and the Royal Bank of Canada, who offer among the lowest rates, both face among the highest elasticity. This suggests that the aggressive pricing these borrowers offer is made with a conscious trade-off to attract less volume.

### **Lender's non-pecuniary preference: $\psi_j$ (capturing $\omega_{ijt}$ )**

The estimated  $\psi_j$  has a median of 12 bps, a mean of 13 bps, and an interquartile range of (7.3 bps, 14.6 bps). One way to interpret these estimates is to note that  $\psi_j$  reflects the marginal utility on lending the *first* dollar. In other words, all else equal, the borrower at the 25<sup>th</sup> percentile would have to offer 7 bps more than the borrower at the 75<sup>th</sup> to attract the same first dollar of lending.<sup>43</sup>

Borrowers seldom stop at one dollar. This explains why Goldman Sachs is estimated to command a low  $\psi_j$  even though it gets away with paying among the lowest rates: Goldman Sachs manages to borrow only very little at the low rate that it offers. In

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<sup>43</sup>In the model,  $\omega_{ijt}$  (whose conditional mean is  $\psi_j$ ) enters the lender's utility as a multiplier to gross repo rates. Here, I suggest an additive increase heuristically because gross repo rates are close to 1 and the first order condition is in based on the logs of  $R_{jt}$  and  $\omega_{ijt}$ .

contrast, other borrowers such as Wells Fargo can borrow much more by paying a slightly higher rate, and are estimated to have higher  $\psi_j$ . Viewed this way,  $\psi_j$  is a preference index that takes into account both better rates and higher volumes.

One possible explanation for lenders exhibiting borrower-specific preferences is that borrowers vary in how consistently they borrow. I find that my estimated parameters do indeed correlate with measures of borrower’s reliability in repo activities. I proxy a borrower’s reliability with her average coefficient of variation in volume vis-à-vis lenders:  $\overline{CoeiVar}_j = \text{mean}_j(\frac{SD_{ij}(vol_{ijt})}{\text{mean}_{ij}(vol_{ijt})})$ . The lower the coefficient of variation, the more reliable a borrower is in using her balance sheet to take on repo loans. In Figure 5, we see that the estimated  $\psi_j$  are strongly and negatively correlated with borrower’s average coefficient of variation. In Table 8, I explore the correlation between estimated  $\psi_j$  with the average and the median of borrower’s coefficient of variation (Models (1) and (2)), and with borrower’s creditworthiness as measured in CDS rates (Models (3) through (5)). The conventional CDS contract varies by jurisdiction,<sup>44</sup> yet even after controlling for jurisdictions, that is, comparing estimated  $\psi_j$  with CDS rates among borrowers within the same jurisdiction, CDS rates still do not appear to be a significant predictor of  $\psi_j$  (Models (4) and (5)). In contrast, measures of borrower’s reliability are strongly correlated with estimated  $\psi_j$ .

**Borrower’s markdown:**  $\frac{Q_{jt}}{Q'_{jt}}$

Having estimated  $\alpha_{it}$  and  $\omega_{ijt}$  in the lender’s problem, we can now calculate borrower’s markdown in Equation 3. In the cross-section, the time-series average of each borrower’s markdown falls within a range of 45 bps, and has an interquartile range of (18 bps, 31 bps); see Appendix Table A1. Compared to the cross-section of borrowers’ time-series

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<sup>44</sup>The most common CDS terms are no restructuring (XR) in the U.S., modified restructuring (MM) in the EU, and full-restructuring (CR) in Japan.

average repo rates,<sup>45</sup> which has a range of 6 bps, we see that the observed dispersion in repo rate belies a much larger dispersion in borrowers' markdowns.

The magnitude of a borrower's markdown depends on both the lenders' preference for that borrower ( $\psi_j$  of  $\omega_{ijt}$ ), and the lenders' aversion to concentration ( $\alpha_{it}$ ). Specifically, preference for investment stability differentiates lending to different borrowers, making each borrower a local monopsony over her funding needs. How much rent a borrower can then extract depends on how easily lenders can substitute away and is thus linked to lenders' concentration aversion. In deriving borrower's markdown from Equation 3, we moreover see a possible reason behind borrowers' divergent markdowns. Because borrowers' value from repo intermediation,  $S_{jt}$ , is net of regulatory cost, for borrowers whose scarce balance sheets can be used for more lucrative trades, repo intermediation has a higher opportunity cost. Such borrowers have less potential rent to claim and therefore choose to not consistently engage in repo borrowing.

It is instructive to also look at the time series of borrowers' markdown. In Figure 6, I plot the time series of the median borrower's markdown through the estimation period. The average of the median markdown over my estimation period is 20.7 bps. Compared to the 5.7 bps average spread between the median Triparty repo rate and lenders' outside option, we see that borrowers extract 78% of the  $(20.7 + 5.7 =)$  26.4 bps total surplus in the Triparty market.

These estimates of Triparty borrowers' markdowns constitute the first quantification of market power in a wholesale funding market, and offer new interpretations to observed funding spreads. Several recent studies have estimated, in various markets, the difference between the rate that large financial intermediaries pay on funding and the implied rate

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<sup>45</sup>Net of  $R_{zt}$  (i.e. 1-day Treasury bill yield before 2014 and the RRP rate after) to be comparable across interest rate environments.

when that funding is used (e.g., [van Binsbergen et al. \(2021\)](#), [Song and Zhu \(2019\)](#)). One paper, [Fleckenstein and Longstaff \(2020\)](#), is particularly relevant. The authors calculate the basis between the rate paid by intermediaries in the Treasury cash market and the rate received by intermediaries as implied in the Treasury futures market. Over my sample period, this Treasury cash-futures basis is about 47.6 bps. This basis includes both the regulatory cost for buying and selling the Treasury security and the economic benefit for doing this intermediation, the latter of which my model features. As Triparty repo can be used to finance Treasury purchase in the cash market,<sup>46</sup> my estimate of the 20.7-bps markdown implies a balance-sheet cost (regulatory cost) of about 27 bps. Furthermore, my estimate suggests that almost half of this empirically observed funding spread could in fact be owing to market power.

Finally, there is noticeable a 8-bps drop in the level of the markdown before (average 24.9 bps) vs. after (average 17.0 bps) the introduction of the RRP. Markdowns on Triparty create a wedge between the Triparty repo rate and the rate intermediated by borrowers to customers in downstream markets. How much of this 8-bps reduction in markdown owes to the Fed’s action through the RRP? I answer this question by comparing my estimated markdown with the markdown in a counterfactual world where the RRP did not exist.

## 6 Counterfactual

In this section, I first calibrate a version of the borrower’s problem. I then combine estimates from the lender’s and the borrower’s problem to consider two policy questions through counterfactual analyses. First, what would happen to the Triparty rate and the

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<sup>46</sup>The Treasury repo rates used in [Fleckenstein and Longstaff \(2020\)](#) are obtained from the dealer-to-dealer bilateral market, where collateral posting requires specifying the CUSIPs of the Treasury securities used.

rate intermediated to the broader market if the RRP were not established? Second, how would the importance of the RRP change if the 2016 Money Market Fund Reform did not happen?

### 6.1 Calibrating borrower's problem

The relationship between borrower's optimal rate, her marginal benefit, and her mark-down, as shown in Equation 3, remains valid irrespective of the parameterization of borrower's intermediation value. I now specify the dependence of borrower intermediation value on quantity as:  $S_{jt} = \hat{S}_{jt} - \zeta \cdot \log(Q_{jt})$ . This functional form reflects possible diminishing marginal returns in the quantity of funding. The first-order condition of the borrower's problem now becomes

$$\begin{aligned} \max_{R_{jt}} (S_{jt}(Q_{jt}) \cdot Q_{ijt}(R_{jt}) - R_{jt} \cdot Q_{ijt}(R_{jt})) \\ R_{jt}^* = \underbrace{\hat{S}_{jt} - \zeta - \zeta \log(Q_{jt})}_{\text{marginal benefit from intermediation at } Q} - \frac{Q_{jt}}{Q'_{jt}}. \end{aligned}$$

I calibrate  $\zeta$  using the 2016 Money Market Fund Reform. In 2016, the money market fund industry underwent a major reform aimed at addressing practices that made the MMF industry vulnerable during the financial crisis of 2007-2008. One of the biggest changes is the mandate for prime funds to keep a floating instead of fixed NAV. This caused an outflow of AUM from prime funds, which mostly invest in unsecured securities such as commercial paper, to government funds, which mostly invest in Treasury securities and could keep using a fixed NAV. As Appendix Figure A3 illustrates, the share of government funds increased to about 75% from 25%. This happened against a backdrop of almost constant total AUM in MMFs. Government funds typically keep a larger



fraction of their AUM in overnight cash.<sup>47</sup> Consequently, the amount of overnight cash in the industry increased from about 10% of AUM in 2015 to almost 20% in 2017.

The MMF reform increased the amount of cash available for repo. As this increase is plausibly exogenous to other variations in borrowers' marginal benefit from intermediation, if borrowers drop their repo rates around the MMF Reform, that decrease likely reflects a deterioration in intermediation value due to increased funding quantity. I therefore use the MMF reform as an instrument for additional funding that borrowers have to absorb, and estimate the corresponding repo rate sensitivity. Specifically, I construct an indicator of MMF reform that takes the value 1 on or post October 2016, when the MMF reform was fully implemented, and take the value 0 before, and I estimate  $\log(R_{jt}) - \log(R_{zt}) = b_1 \widehat{vol}_{jt} + BorrowerFE + e_{1,jt}$ , where  $\widehat{vol}_{jt} = b_0 \mathbf{1}_{t \geq 201610} + BorrowerFE + e_{0,jt}$ . I estimate using observations in the one year before and after October 2016. Results of the estimation are summarized in Appendix Table A2. On average, a borrower had to absorb \$2.1b more because of MMF reform, and each additional billion of funding lowered the repo rate she offered by about 0.6 bps.

This estimate of  $\frac{d \log R}{dQ}$  can be used to inform  $\zeta$ , as  $\zeta = -2QR \cdot \frac{d \log R}{dQ}$ . Based on the average value of  $Q, R$  in the estimation period, I derive a  $\zeta$  of  $1.98 \times 10^{-3}$ . In Appendix Section A, I discuss the sensitivity of counterfactual results to different values of  $\zeta$ .

## 6.2 Triparty without RRP

The Fed instituted the Reverse Repo Facility in anticipation of increasing its policy interest rate. The RRP is thought to have put a floor on repo rates, which allowed the

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<sup>47</sup>Government funds can only invest in a limited number of securities. To improve their yield, government funds invest heavily into longer maturity government securities. To comply with regulations on the fund's average maturity, they keep a larger overnight cash portfolio. Industry participants refer to this as the "barbell strategy".

Fed to successfully raise the interest rate four times between 2015 and 2017, even as the Fed’s usual tool – reserve supply adjustment – was made obsolete by the abundance of reserves during this period. If the RRP were not available, would the Triparty repo rate still have conformed to the Fed’s policy target? What would be the rate intermediated from Triparty to downstream markets in the absence of the RRP?

To assess the effect of the RRP, I start by assuming that, in the absence of the RRP, the Triparty lenders would have as their outside option the realized historical 1-day Treasury bills yield. As Panel A of Figure 7 illustrates, this new outside option is lower than the RRP between 2014 and 2017, by about 12 bps on average. Given this change, repo borrowers would lower the rates they offer. Panel B of Figure 7 illustrates the median counterfactual repo rate. On average from October 2014 to November 2017, the counterfactual median Triparty repo rate is down 8 basis points from historical, which puts the median Triparty rate at 3 bps below the lower bound of the Federal Reserve’s policy target. A drop in the repo rates notwithstanding, because the rate offered by borrowers would still be higher than the new outside option, the total volume to repo borrowers would actually increase by on average \$48b per month, as illustrated in Panel C of Figure 7.

Although the total volume lent to Triparty borrowers would increase, this increase is not enough to completely offset the amount of cash the lenders used to place at the RRP. Consequently, in this first scenario (Scenario #1), about \$101b/month would have to be redirected from the RRP to the new outside option, Treasury bills. This represents a sizeable additional demand for Treasury securities, and likely would have changed the equilibrium Treasury yield.

I therefore consider a second scenario (Scenario #2) where, as in Scenario #1, lenders

put the cash not lent to repo borrowers in Treasury bills instead of the RRP. However, the yield that lenders get from investing in Treasury bills is no longer the historical 1-day yield. Instead, I allow the Treasury market to respond to inflows of cash, even as I allow the Triparty agents to re-optimize concurrently. Using the Treasury elasticity estimate from [Greenwood et al. \(2015\)](#), where 1 percentage point decrease in  $\frac{\Delta Treasury}{GDP}$  leads to 38.6 bps decrease in Treasury yield, I search for the new Triparty equilibrium, letting both the Triparty market and the Treasury market adjust.<sup>48</sup> Table 9 reports this new equilibrium relative to historical. The counterfactual median Triparty rate is lower in this second scenario than in the first, because the Treasury yield declines in response to inflows of cash displaced from the RRP. Indeed, the new median Triparty rate is 15 bps below historical. This puts the counterfactual median Triparty repo rate at 11 basis point below the lower bound of the Fed’s policy target. Yet the rate intermediated to the broader financial market falls by only 7.7 bps, as 49% (7.6 bps) of the counterfactual rate drop reflects increased borrower’s market power.

These counterfactual estimates show that the RRP buoyed up the Triparty repo rate by as much as 60% of a typical 25-bps rate hike, and that the RRP tightened the wedge in intermediation. In fact, half of the RRP’s impact on rate comes from constraining borrowers’ market power and narrowing their markdowns. Two factors make the RRP an excellent outside option for the lenders. First, RRP offers a rate that’s higher than plausible market alternatives. Second, and perhaps more crucially, the RRP is a fixed-rate facility whose promised rate isn’t buffeted by sizeable inflows and outflows. Together, these qualities make the RRP an effective monetary policy tool that materially improves the conformance of market rates to the Fed policy rates.

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<sup>48</sup>See Appendix Section A for the sensitivity of counterfactual results to different values of Treasury yield sensitivity.

### 6.3 Absence of MMF Reform

The 2016 MMF Reform discussed in Section 6.1 represented a major change to the money market fund industry. What would have happened to the Triparty market if the Reform didn't happen? Specifically, if the share of government funds remained at their 2015 level, what would the consequently smaller supply of repo funding in 2016 and 2017 mean for the effect of the RRP?

I consider this experiment in two steps and summarize the results in Table 9. First, I assume that while the MMF Reform did not happen, the RRP was still available. In this third scenario (Scenario #3), the lenders' overnight cash portfolios in 2016 and 2017 are assumed to be at the same percent of AUM as in 2015. As lenders' portfolios become smaller, they lend less to repo borrowers, pushing up borrowers' marginal benefit from intermediation, and the counterfactual median Triparty rate in this third scenario would in fact be higher than historical.

Next, I bring the policy discussions together in one scenario by assuming that the MMF Reform didn't happen *and* the RRP were not available *and* the lenders had as their outside option a Treasury market that adjusted to inflows. Relative to the counterfactual of no MMF Reform (Scenario #3), further removing the RRP lowers the median counterfactual Triparty repo rate by 11 bps. This effect on Triparty repo rate is noticeably less than the 15 bps drop caused by the removal of the RRP in Scenario #2. The effect of the RRP on borrowers' markdowns also shrinks without the MMF Reform. Relative to Scenario #3, removing the RRP widens the median markdown by 6 bps. This change is 25% less than the 8-bps change in markdowns found in Scenario #2.

These differences highlight that the effect of monetary policy tools crucially depends on the interaction among policies. Lenders' reliance on the fixed-rate RRP grows as

they have more cash to deploy. The larger the lender’s portfolio, the more cash the lender has to place in the outside option, and the more critical that this outside option remains attractive even in the face of large inflows. Consequently, any policy that affects the size of lenders’ cash portfolio also alters the effect of the RRP. This consideration bears particular relevance to monetary policy stances that aim to increase the amount of reserves. For instance, the Fed injected a substantial amount of additional reserve at the onset of the COVID-19 pandemic. These reserves expanded MMFs’ portfolios and contributed to daily take-ups of the RRP in excess of \$1 trillion.<sup>49</sup>

## 7 Conclusion

Leveraging the institutional and empirical features of the Triparty repo market, I describe Triparty’s equilibrium using a system of supply and demand. My estimated model reveals substantial market power enjoyed by the Triparty cash-borrowers (dealers). The presence of imperfect competition on this vital wholesale funding market can hinder monetary policy implementation by obfuscating the true condition in wholesale funding markets. The results of this paper help disentangle movements in the supply and demand of funding from fluctuations in market power. Beyond this paper, imperfect competition in the Triparty market may hold the key to understanding the rapid adoption of sponsored repo,<sup>50</sup> an important and recent development in money markets meriting future studies.

The estimated model in this paper moreover enables assessing the Overnight Reverse Repo Facility through counterfactual analyses. By constraining borrowers’ market power,

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<sup>49</sup>Usage of the RRP exceeded \$1 trillion in June 2021. This timing lags the Fed’s reserve injection in March 2020 because reserves were initially held on banks’ balance sheets, and found their way to MMFs only after the moratorium on the Supplemental Leverage Ratio (SLR) expired in spring 2021.

<sup>50</sup>In sponsored repo, Triparty cash-lenders lend directly to customers of Triparty cash-borrowers with the cash-borrower serving as the sponsor on a different platform (FICC). Cash-borrower benefits from no longer having to set aside balance-sheet space, and can therefore offer better rates to both the cash-lender and the customer.

the RRP meaningfully buoyed up the equilibrium Triparty repo rate and tightened the intermediation wedge between the Triparty market and the broader economy. Moreover, the RRP interacts with other policies to concurrently shape competition in the Triparty market. As imperfect competition between financial intermediaries directly affects asset prices and monetary policy implementation, understanding how policies impact intermediaries' competitive environment both separately and jointly ought to form part of any effective policy design.

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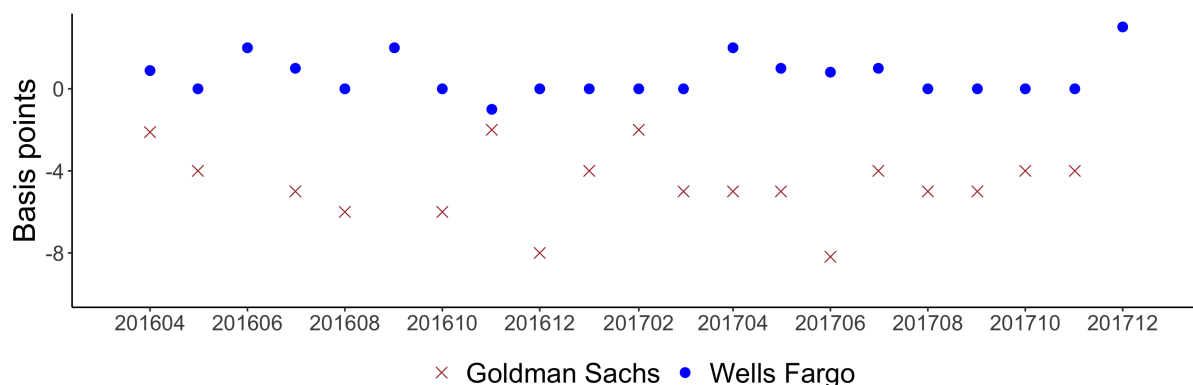
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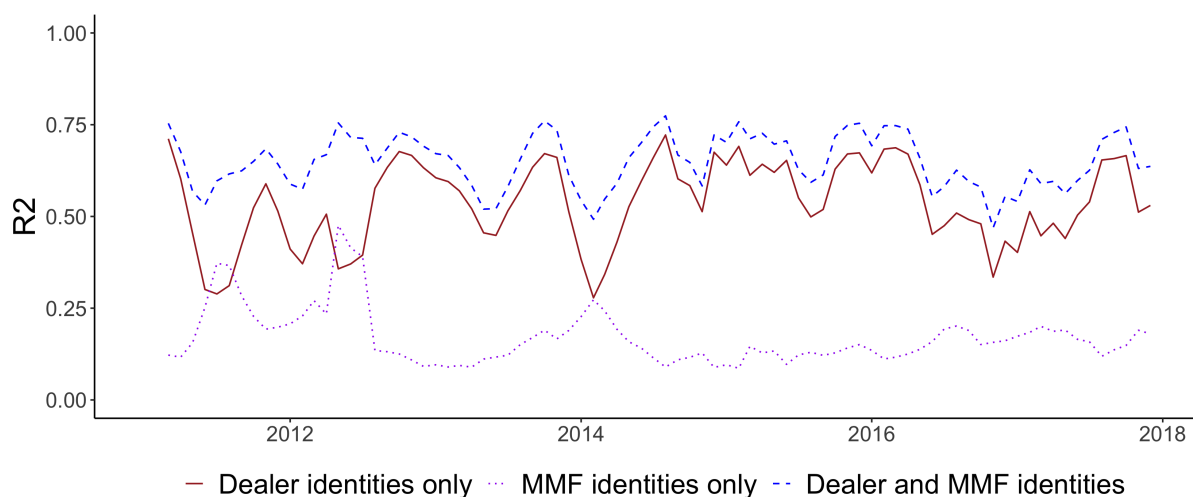
## Tables and Figures

Figure 1: **Select repo rates of BlackRock MMF's lending**



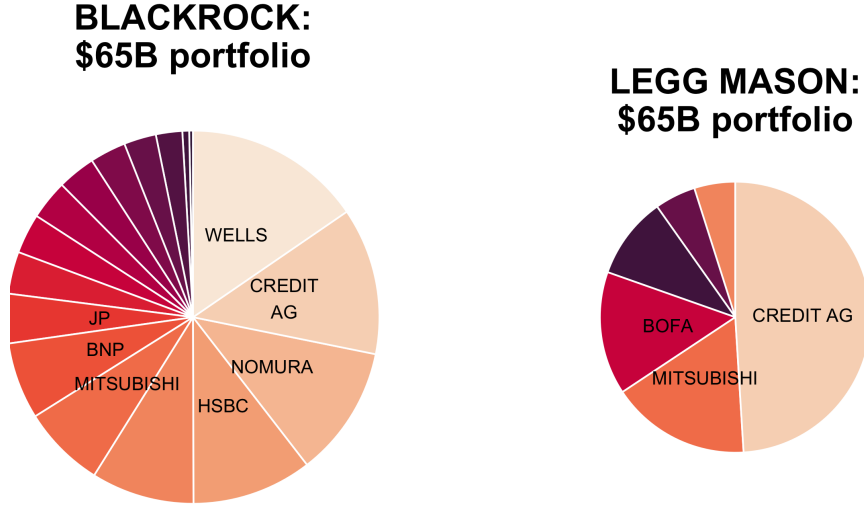
*Notes:* This figure plots the repo rates accepted by BlackRock MMF for lending to Goldman Sachs and Wells Fargo via overnight repo collateralized by Treasury securities with 2% haircut. The repo rates are reported as gross rates less the daily median repo rate and are stated in basis points. Two outliers are omitted: the repo rate by Goldman Sachs was 20 bps below median on September 2016, and 12 bps below median on December 2017.

Figure 2: **Decomposition of cross-sectional variation in rate dispersion**



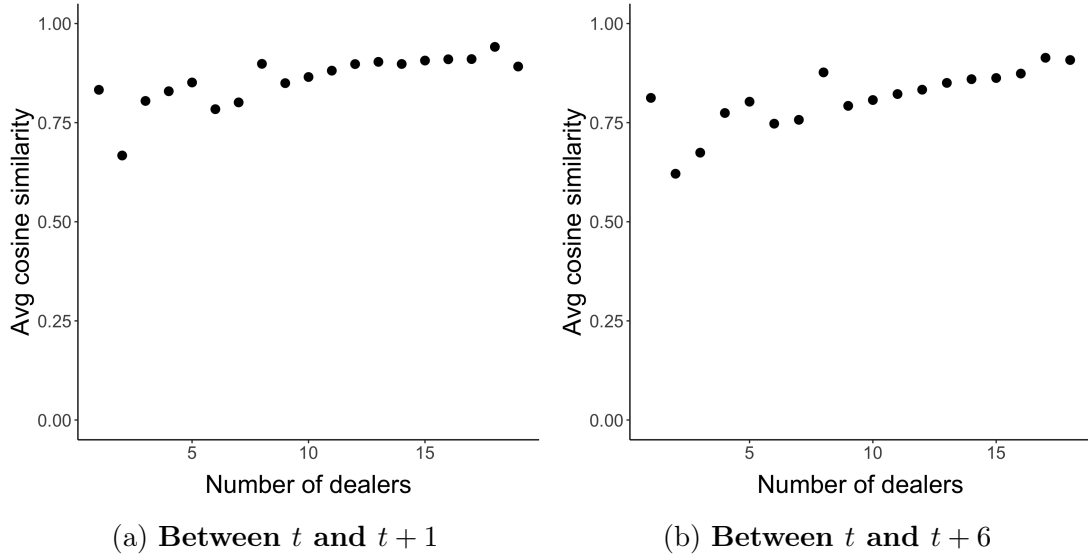
*Notes:* This figure plots the three-month rolling average of the  $R^2$  from monthly cross-sectional regressions of repo rates on MMF and dealer fixed effects. Repo rates are measured as gross repo rates less the daily median repo rate, and are for overnight repo collateralized by Treasury securities with 2% haircut. The solid red line is the  $R^2$  from regressing repo rates on dealer fixed effects, the dotted purple line is the  $R^2$  from regressing repo rates on MMF fixed effects, and the dashed blue line is the  $R^2$  from regressing repo rates on dealer fixed effects and MMF fixed effects. The sample period is from January 2011 through December 2017.

Figure 3: Select MMF repo portfolios on October 31, 2016



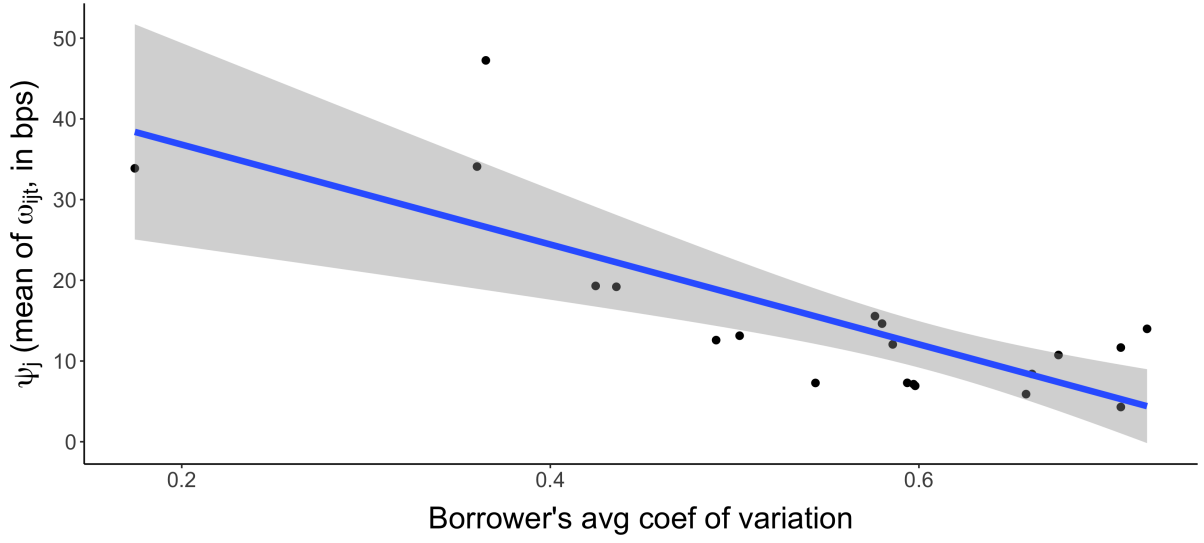
*Notes:* This figure plots the repo lending to dealers by BlackRock and Legg Mason on October 31, 2016. The size of the pie corresponds to BlackRock and Legg Mason's overnight repo lending volume, as labeled. The size of each slice represents the share of the portfolio lent to different dealers.

Figure 4: Stability in MMF overnight portfolios



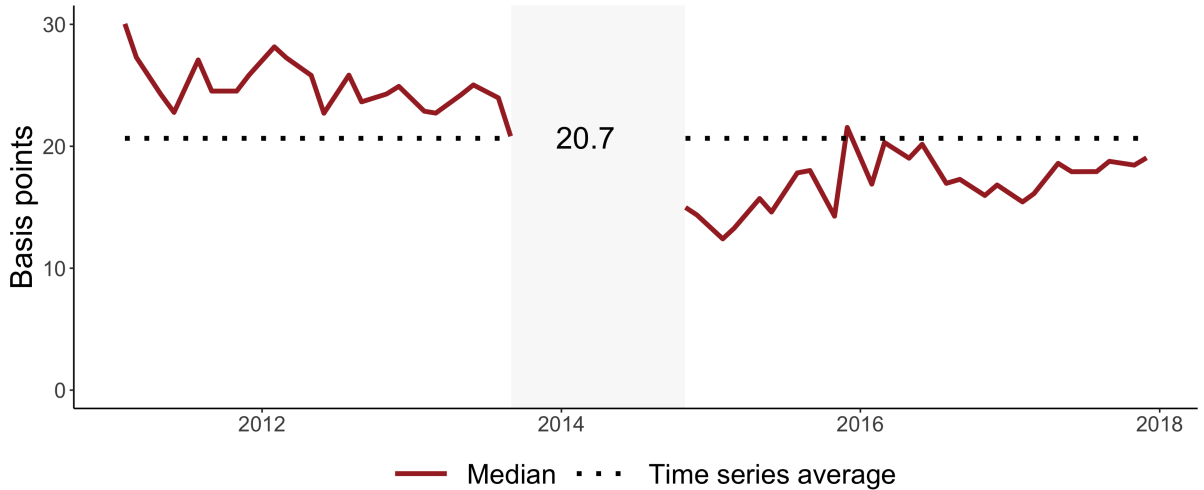
*Notes:* This figure plots the average cosine similarity between MMFs' overnight portfolios at time  $t$  and  $t + n$  against the number of dealers in the portfolio at time  $t$ . Cosine similarity between portfolio  $\mathbf{x}$  and  $\mathbf{y}$  is defined as  $CosSim(\mathbf{x}, \mathbf{y}) = \frac{\mathbf{x} \cdot \mathbf{y}}{\|\mathbf{x}\| \|\mathbf{y}\|}$ . Panel (a) compares portfolios at time  $t$  and at time  $t + 1$ , panel (b) compares portfolios at time  $t$  and at time  $t + 6$ . The sample period is January 2011 through December 2017.

Figure 5: **Correlation between estimated borrower preference and coefficient of variation in volume**



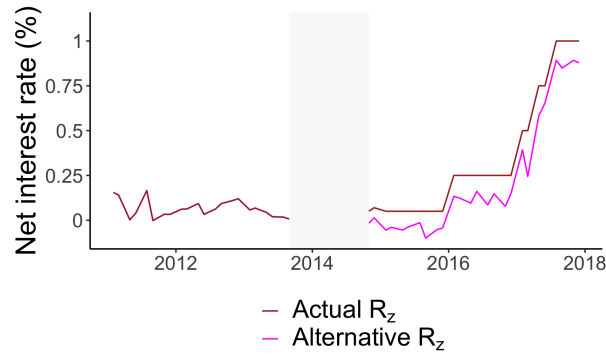
*Notes:* This figure plots estimated  $\psi_j$  against borrower's average coefficient of variation. The blue line represents the fitted value from regressing  $\psi_j$  on borrower's average coefficient of variation and the shaded regions is the 95% heteroskedasticity-robust confidence bands. Borrower's average coefficient of variation is as defined in Section 5.5, and is the by-borrower average of borrower-lender coefficient of variation in repo volume throughout the model estimation period. The model estimation period is January 2011 to December 2017, excluding September 2013 through September 2014 when RRP was first introduced and was in testing, and excluding months that fall on quarter ends.

Figure 6: **Triparty borrower markdown**

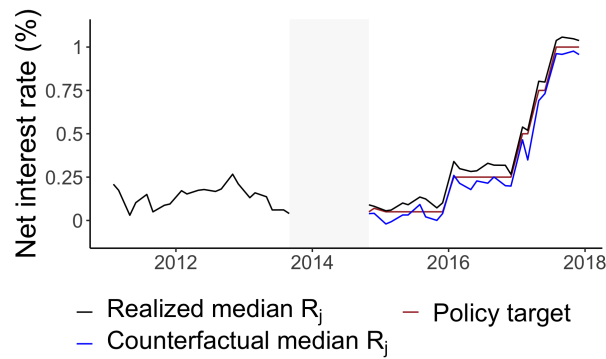


*Notes:* This figure plots, in solid red, the time series variation in the median borrower markdown over the model estimation period. The dotted black line indicates the average of this value over the whole sample. The shaded area correspond to September 2013 through September 2014 when RRP was in testing. The model estimation period is January 2011 to December 2017, excluding September 2013 through September 2014 and months that fall on quarter ends.

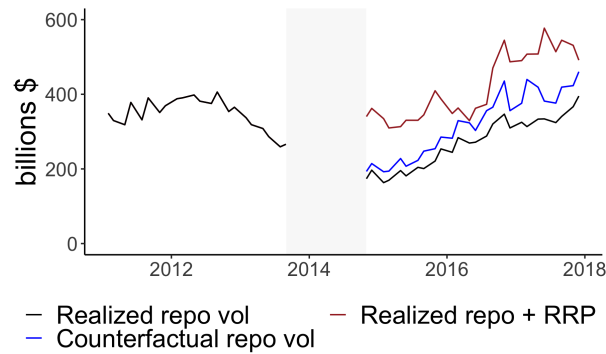
Figure 7: **Scenario #1: no RRP, lenders access historical Treasury yield**



(a) Counterfactual  $R_{zt}$



(b) Counterfactual rate



(c) Counterfactual volume

*Notes:* This figure plots the counterfactual median Triparty repo rate and the total Triparty repo volume in Scenario #1: the RRP were not available in 2014 through 2017 and lenders considered the historical 1-day Treasury yield as the outside option to lending to borrowers. Panel A shows the actual  $R_{zt}$  in red, which is the 1-day Treasury yield before 2014 and the RRP rate after 2014; and it shows the alternative  $R_{zt}$  in pink, which is the 1-day Treasury yield throughout. Panel B shows the counterfactual median Triparty repo rate in blue, against the realized (historical) median Triparty repo rate in black, and the lower bound of the Fed's policy target in red. Panel C shows the counterfactual total repo lending to Triparty dealers in blue, the historical total repo lending to Triparty dealers in black, and the historical total lending to dealers and the RRP in red. The shaded area correspond to September 2013 through September 2014 when the RRP was in testing. The model estimation period is January 2011 to December 2017, excluding September 2013 through September 2014 and months that fall on quarter ends. This figure is best viewed in color.

Table 1: Within dealer characteristics and rate dispersion

	Deviation of Treasury repo rate from median					
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Pair Treasury repo volume	0.013 (0.022)					0.052 (0.041)
Pair vol as percent of MMF		0.049 (0.366)				-0.661 (0.419)
Pair vol as percent of dealer			0.289 (0.245)			0.508 (0.355)
MMF total Treasury repo vol				-0.007 (0.007)		-0.013 (0.013)
MMF number of counterparty					-0.013 (0.011)	-0.011 (0.018)
Dealer + Month FE	Yes	Yes	Yes	Yes	Yes	Yes
Num. obs.	10453	10453	10453	10453	10453	10453
R <sup>2</sup> (full model)	0.227	0.227	0.227	0.227	0.227	0.228
R <sup>2</sup> (proj model)	0.000	0.000	0.000	0.000	0.000	0.002

Standard errors in parentheses.

*Notes:* In this table, repo rates are regressed on MMF characteristics and MMF-dealer pair characteristics, as well as dealer fixed effects and month (time) fixed effects. Repo rates are for lending between MMF-dealer pairs via overnight repo collateralized by Treasury securities with 2% haircut, and they are measured as deviation from the daily median. “Pair Treasury repo volume” is the amount of overnight repo lending collateralized by Treasury securities with 2% haircut on the day of the observation between a pair of MMF-dealer. “Pair vol as percent of MMF” is the pair’s volume as a percentage of the MMF’s total lending via overnight repo collateralized by Treasury securities with 2% haircut. “Pair vol as percent of dealer” is the same ratio against the total borrowing of the dealer. “MMF total Treasury repo vol” is the MMF’s total amount of lending via overnight repo collateralized by Treasury securities with 2% haircut, on the day of the observation. “MMF number of counterparty” is the number of dealers that MMF lends to via overnight repo collateralized by Treasury securities with 2% haircut on the day of observation. The sample period is from January 2011 through December 2017. Standard errors are clustered by dealer. \*, \*\*, and \*\*\* denote significance levels at 10%, 5%, and 1% confidence levels.

Table 2: **Model fit with dealer vs. relationship FE**

	Deviation of Treasury repo rate from median			
	Model 1	Model 2	Model 3	Model 4
Dealer FE	Yes	No	Yes	No
MMF-Dealer Pair FE	No	Yes	No	Yes
Year FE	No	No	Yes	Yes
N	10453	10453	10453	10453
Num of FE	20	271	26	277
$R^2$	0.18	0.24	0.19	0.25
AIC (in 1000s)	41.53	41.22	41.38	41.07
BIC (in 1000s)	41.68	43.19	41.58	43.08

*Notes:* This table reports the goodness of fit for regressions of repo rates on dealer fixed effects or MMF-dealer pair fixed effects. Repo rates are for lending between MMF-dealer pairs via overnight repo collateralized by Treasury securities with 2% haircut, and they are measured as deviation from the daily median. Goodness of fit measures are  $R^2$ , Akaike information criterion (AIC), and Bayesian information criterion (BIC). The estimation sample is January 2011 through December 2017.

Table 3: **MMF size and portfolio composition**

	Number of dealers	Median portfolio share	Max portfolio share	Min portfolio share
	Model 1	Model 2	Model 3	Model 4
Constant	1.403 (1.021)	0.266*** (0.037)	0.399*** (0.033)	0.188*** (0.042)
Log(MMF size)	3.022*** (0.290)	-0.067*** (0.013)	-0.074*** (0.012)	-0.055*** (0.014)
Num. obs.	1467	1467	1467	1467
$R^2$	0.556	0.524	0.369	0.439

Standard errors in parentheses.

*Notes:* This table reports regressions of the extensive and intensive margins of MMFs' portfolio on MMFs' overnight portfolio size and a constant. Model (1) uses the number of dealers to which a MMF lends. Models (2) through (4) use, respectively, the median, the maximum, and the minimum share of MMF's portfolio lent to dealers. The sample period is from January 2011 through December 2017. Standard errors are clustered by MMF. \*, \*\*, and \*\*\* denote significance levels at 10%, 5%, and 1% confidence levels.



Table 4: Dealer repo activities on quarter-ends

	Dealer repo volume ( $vol_{jt}$ )		Log(dealer repo volume)		Dear rate	
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 5
QE	0.843 (0.733)	0.716 (0.872)	0.087 (0.087)	0.078 (0.083)	-0.037 (0.297)	-0.037 (0.297)
QE * Dealer EU	-7.754*** (1.205)	-7.716*** (1.227)	-0.500*** (0.120)	-0.496*** (0.112)	-0.086 (0.348)	-0.086 (0.348)
QE * Dealer JP	-0.814 (2.711)	-0.761 (2.540)	-0.137 (0.227)	-0.134 (0.199)	0.292 (0.611)	0.292 (0.611)
QE * Dealer UK	-4.394*** (1.659)	-4.331*** (1.477)	-0.326** (0.150)	-0.322** (0.130)	0.097 (0.344)	0.097 (0.344)
QE * Dealer US	-1.658 (1.396)	-1.548 (1.424)	-0.157 (0.112)	-0.150 (0.107)	0.138 (0.383)	0.138 (0.383)
Avg change: EU, UK	-5.231	-5.308				
Avg change: CA, JP, US	0.019	-0.054				
Dealer HQ FE	Yes	Yes	Yes	Yes	Yes	Yes
Quarter FE	No	Yes	No	Yes	Yes	Yes
Num. obs.	1415	1415	1415	1415	1415	1415
R <sup>2</sup>	0.098	0.251	0.078	0.258	0.109	0.109

Standard errors in parentheses.

*Notes:* This table reports regressions of dealer's overnight repo volume and rate on indicators of quarter-ends and the dealer's headquarter jurisdiction. The dependent variable is dealer's repo volume in Models (1) and (2), the log of dealer's overnight repo volume in Models (3) and (4), and the dealer repo rate in Model (5). Headquarter jurisdictions are Canada (CA), the European Union (EU), Japan (JP), the United Kingdom (UK), and the United States (US). "Avg change: EU, UK" is calculated as  $(QE * DealerEU + QE * DealerUK + QE * 2)/2$ . "Avg change: CA, JP, US" is calculated as  $(QE * DealerJP + QE * DealerUS + QE * 3)/3$ . Dealer's repo rate is defined as the volume-weighted average of repo rates between a dealer and all lenders in overnight repo collateralized by Treasury securities with 2% haircut. It is reported as the gross rate less the daily median, in basis points. The sample period is from January 2011 through December 2017. Standard errors are robust to heteroskedasticity. \*, \*\*, and \*\*\* denote significance levels at 10%, 5%, and 1% confidence levels.

Table 5: Inverse semi-elasticity using Treasury auction IV

	1st stage: $vol_{jt}$		IV: $R_{jt}-R_{zt}$		Alt. 1st		Alt. IV	
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 5	Model 6
Non-bill Treasury offer amount	46.79*** (14.66)	16.29** (6.76)						
Treasury offer * borrower share				241.64** (97.20)				
Vol_jt (fit)			1.57** (0.67)		1.57** (0.61)			
Vol_jt							0.01 (0.01)	
Dealer FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cluster-robust F-stat		5.81		6.18				
Anderson-Rubin 95% CI			(0.5, 8.6)		(0.6, 7.9)			
Num. obs.	821	821	821	821	821	821	821	821

Standard errors in parentheses.

*Notes:* This table reports the instrumental variable estimations of the inverse semi-elasticity facing borrowers. Models (1) and (2) are first-stage regressions of borrower's overnight repo volume on the amount of non-bill Treasury securities offered to be auctioned and settled on the same day as MMF N-MFP reporting dates. Model (3) regresses the difference between borrower's repo rate and the outside option, on borrower's overnight repo volume, as instrumented using model (2). Models (4) and (5) are similar to models (2) and (3) but uses as the instrument: the product of Treasury auction offer (as defined above) and each borrower's average share of the total Triparty overnight repo volume. Model (6) regresses borrower's repo rates on volume, without using an instrument. Borrower's repo rate is defined as the volume-weighted average of repo rates between a borrower and all lenders in overnight repo collateralized by Treasury securities with 2% haircut. The outside option is defined as the imputed 1-day Treasury bill yield before September 2013 and the rate on RRP after September 2014. The estimation period is January 2011 to December 2017, excluding September 2013 through September 2014 when RRP was in testing, and excluding months that fall on quarter ends. Standard errors are clustered by month (frequency of observation). \*, \*\*, and \*\*\* denote significance levels at 10%, 5%, and 1% confidence levels.

Table 6: Model parameter estimates via indirect inference

Parameter	Estimate	Bootstrapped 95% CI	Parameter	Estimate	Bootstrapped 95% CI
$\beta_0 \cdot 1e3$	2.28	(1.92, 4.12)	$\psi_j$		
$\beta_1 \cdot 1e3$	-7.92	(-8.71, -7)	Bank of America	10.75	(6.93, 11.12)
$\sigma^2$	6.05	(4.88, 12.29)	Barclays	13.99	(10.57, 16.07)
$k(shape)$	137.43	(134.98, 137.45)	BNP Paribas	7.30	(2.21, 7.93)
			Citi	12.59	(9.91, 14.36)
			Crédit Agricole	19.31	(15.6, 19.92)
			Credit Suisse	11.67	(9.69, 13.84)
			Deutsche Bank	15.56	(11.93, 16.93)
			Goldman Sachs	8.40	(6.31, 9.24)
			HSBC	7.13	(3.93, 7.15)
			JP Morgan	5.90	(3.71, 6.22)
			Mitsubishi	13.14	(10.84, 14.84)
			Natixis	33.87	(29.55, 37.79)
			Nomura	47.25	(40.96, 51.63)
			Nova Scotia	7.28	(4.77, 8.3)
			Royal Bank of Canada	6.93	(4.94, 7.91)
			Royal Bank of Scotland	12.06	(8.18, 12.85)
			Société Générale	14.63	(11.71, 15.38)
			Sumitomo	34.09	(26.84, 40.9)
			UBS	4.30	(1.67, 6.84)
			Wells Fargo	19.20	(16.11, 20.63)

Block bootstrapped 95% confidence interval in parentheses.

*Notes:* This table reports the estimates of the parameters in the lender's problem using indirect inference, as discussed in Section 5.  $\beta_0, \beta_1$  are parameters of  $\alpha_{it}$ :  $\alpha_{it} = \beta_0 + \beta_1 \cdot \sqrt{y_{it}}$ .  $\psi_j, k$  are parameters of  $\nu_{ijt}$ :  $\nu_{ijt} \sim 1 + \text{Gamma}(shape = k, scale = \psi_j/k)$ ; the random variable defined by *Gamma* is scaled by  $1 \times 10^{-4}$ .  $\sigma^2$  is the parameter of  $\epsilon_{jt}$ :  $\epsilon_{jt} \sim \text{LogNormal}(\frac{-\sigma^2}{2}, \sigma^2)$ ; where  $\epsilon_{jt}$  is scaled by  $5 \times 10^{-5}$ . Reported in parentheses are the bootstrapped 95% confidence interval. Bootstraps are done by time (month) blocks (clusters). The model estimation period is January 2011 to December 2017, excluding September 2013 through September 2014 when RRP was in testing, and excluding months that fall on quarter ends.

Table 7: **Model parameter estimates via MLE**

	Indicator for lending	
	No adjustment	Incidental parameter bias corrected
Log(lender portfolio size) [ $\delta$ ]	0.642*** (0.064)	0.626*** (0.063)
Pair FE included	210	210
Log Likelihood	-4375.801	-4375.831
Deviance	8751.601	8751.663
Num. obs.	8862	8862

Standard errors in parentheses.

*Notes:* This table reports the estimates of the parameters in the lender's problem using maximum likelihood, as discussed in Section 5. Both specifications include indicators for borrower-lender pair, and the model in column 2 corrects for potential incidental parameter bias from including fixed effects in a non-linear model. The model estimation period is January 2011 to December 2017, excluding September 2013 through September 2014 when RRP was in testing, and excluding months that fall on quarter ends. \*, \*\*, and \*\*\* denote significance levels at 10%, 5%, and 1% confidence levels.

Table 8: Estimated  $\psi_j$  vs. borrowing reliability and CDS

	Estimated $\psi_j$				
	Model 1	Model 2	Model 3	Model 4	Model 5
Constant	49.187*** (8.401)	43.697*** (6.118)	11.308* (5.619)		
Average coef of variation	-61.868*** (13.689)				
Median coef of variation		-54.068*** (9.996)			
Average CDS: last 3 days of month			0.097 (0.128)	0.274 (0.191)	
Average CDS					0.259 (0.185)
Dealer HQ FE	No	No	No	Yes	Yes
Num. obs.	20	20	20	20	20
R <sup>2</sup>	0.618	0.579	0.022	0.558	0.552

Standard errors in parentheses.

*Notes:* This table reports the regression of the estimated preference parameter,  $\psi_j$  (capturing  $\omega_{ijt}$ ), on measures of borrower's borrowing reliability and creditworthiness. "Average coef of variation" is the average of a borrower's coefficients of variation in volume vis-à-vis all lenders:  $\overline{CoeffVar}_j = \overline{mean}_j(\frac{SD_{ij}(vol_{ijt})}{mean_{ij}(vol_{ijt})})$ . "Median coef of variation" is the median of a borrower's coefficients of variation. "Average CDS on last 3 days of month" is the average a borrower's credit default swap rate on the last 3 business days of each month in the model estimation period. "Average CDS" is the average of a borrower's CDS rate over the model estimation period. CDS rates are for 6M debt for all borrowers except for Mitsubishi and Royal Bank of Scotland, who only have 5Y CDS. CDS rates are moreover for contracts in local currency (except for the Canadian banks, whose CDS are in U.S. dollars), and follow the most common CDS convention, which is no restructuring (XR) in the U.S. and Canada, modified restructuring (MM) in the EU, and full-restructuring (CR) in Japan. The model estimation period is January 2011 to December 2017, excluding September 2013 through September 2014 when RRP was in testing, and excluding months that fall on quarter ends. Standard errors are robust to heteroskedasticity. \*, \*\*, and \*\*\* denote significance levels at 10%, 5%, and 1% confidence levels.

Table 9: **Summary of results from counterfactual analyses**

Scenario	Market	Rate change	Markdown change	Volume change
1. No RRP, historical Treasury yield	Triparty repo	↓ 8 bps (3 bps below target)	↑ 4 bps	↑ \$48b
2. No RRP, Treasury yield adjusts	Triparty repo	↓ 15 bps (11 bps below target)	↑ 8 bps	↑ \$96b
	Treasury	↓ 11 bps	-	↑ \$54b
3. No MMF reform, keep RRP	Triparty repo	↑ 1 bp	↑ 3 bps	↓ \$69b
4. No MMF reform, no RRP, Treasury yield adjusts	Triparty repo	↓ 10 bps (11 bps below Scenario #3)	↑ 9 bps (6 bps above Scenario #3)	↓ \$13b
	Treasury	↓ 3 bps	-	↑ \$13b

*Notes:* This table summarizes the results from different counterfactual scenarios. “1. No RRP, historical Treasury yield” is the scenario where, between 2014 and 2017, lenders see the realized 1-day Treasury yield instead of the RRP rate as the outside option to lending to borrowers via overnight repo. “2. No RRP, Treasury yield adjusts” is the scenario where, between 2014 and 2017, lenders see the 1-day Treasury yield instead of the RRP rate as the outside option to lending to borrowers via overnight repo, but the Treasury yield also responds to changes in demand. “3. No MMF reform, keep RRP” is the scenario where, between October 2016 and 2017, lenders’ overnight cash portfolios are kept at the same fraction of AUM as they were in 2015. “4. No MMF reform, no RRP, Treasury yield adjusts” is the scenario where, between October 2016 and 2017, lenders’ overnight cash portfolios are kept at the same fraction of AUM as they were in 2015; moreover, lenders see the realized 1-day Treasury yield as the outside option to lending to borrowers via overnight repo, and the Treasury yield also responds to changes in demand. The measure of “below target” is relative to the lower bound of the Fed’s policy target band. “Rate change” and “Markdown change” refer to the time series average of the difference between the historical and the median counterfactual repo rate and markdown, respectively. “Volume change” refers to the time series average of the difference between the historical and the counterfactual total volume of overnight repo lent to borrowers in the sample. Based on parameters estimated in the model estimation period of January 2011 to December 2017, excluding September 2013 through September 2014 when RRP was in testing, and excluding months that fall on quarter ends.

## Appendix

### A Counterfactual sensitivity to calibrated parameters

The main policy experiment, which is Scenario #2 in Table 9, considers a world where the RRP were not available, and the Triparty lenders viewed the 1-day Treasury bill yield as the return on their outside option. To conduct the counterfactual analyses, I needed estimates of the parameters in the lender’s problem (Tables 6, 7), as well as a calibrated sensitivity of borrower’s marginal benefit from intermediation to funding quantities, and an assumption of how the 1-day Treasury yield changes to inflows of cash. In this section, I discuss how the counterfactual results change when the calibrated and assumed parameters change.

#### A.1 Sensitivity to $\zeta$

In Section 6.1, I parameterize the borrower’s optimal rate setting in Equation 3 by specifying the dependence of borrower’s intermediation value on quantity:  $S_{jt} = \hat{S}_{jt} - \zeta \cdot \log(Q_{jt})$ . The first-order condition of the borrower’s problem becomes  $R_{jt}^* = \hat{S}_{jt} - \zeta - \zeta \log(Q_{jt}) - \frac{Q_{jt}}{Q_{jt}^*}$ . I use the 2016 MMF Reform as an instrumental variable and estimate that the Triparty borrowers lower their repo rate by about 0.610 bps for each additional billion of funding they have to absorb (Appendix Table A2). From this, I calibrate  $\zeta$  to be  $1.98 \times 10^{-3}$ . There are estimation errors associated with the borrower’s rate response: the standard error on the point estimate of 0.610 bps is 0.226 bps. I explore the implication of this estimation error and re-calculate the counterfactual equilibrium in Scenario #2 by using a borrower’s rate response that’s 1 standard error above or 1 standard error below the point estimate. Appendix Table A3 summarizes the results.

When borrowers’ marginal benefit from intermediation decreases more rapidly with funding volume (Variation 1,  $\zeta$  of  $2.71 \times 10^{-3}$ , *more* sensitive), the equilibrium Triparty rate would be lower than in the original counterfactual (Variation 0). This is because borrowers are more reluctant to take on additional repo funding, pushing more cash into Treasury bills, and suppressing the lender’s outside option further. Borrowers’ reluctance

also lowers their markdown relative to the original. When borrowers' marginal benefit from intermediation decreases less rapidly with funding volume (Variation 2,  $\zeta$  of  $1.25 \times 10^{-3}$ ), the opposite happens. The equilibrium Triparty repo rate in Variation 2 is higher than in the original because borrowers take on more funding and the Treasury yield is not as impacted. At the same time, borrower's markdown expands slightly. Importantly, all of these changes are quite small, suggesting that the counterfactual results are not driven primarily by the calibration of  $\zeta$ .

## A.2 Sensitivity to Treasury elasticity

In Scenario #2, the 1-day Treasury yield adjusts to cash inflows. Taking into account a possible yield response in the Treasury market is not only more realistic but also meaningfully changes the counterfactual results. In Table 9, when the Treasury yield was held fixed at its historical values (Scenario #1), the counterfactual median Triparty repo rate is on average 8 bps below historical. This impact is only half of that in Scenario #2 (15 bps), where the Treasury yield is allowed to adjust to cash inflows. In Scenario #2, the sensitivity of Treasury bill's yield to changes in demand is taken from Greenwood et al. (2015). Authors in Greenwood et al. (2015) arrive at their estimate exploiting the seasonal variation in Treasury supply driven by the Federal tax calendar, and their estimate has a standard error of 10.35 bps.

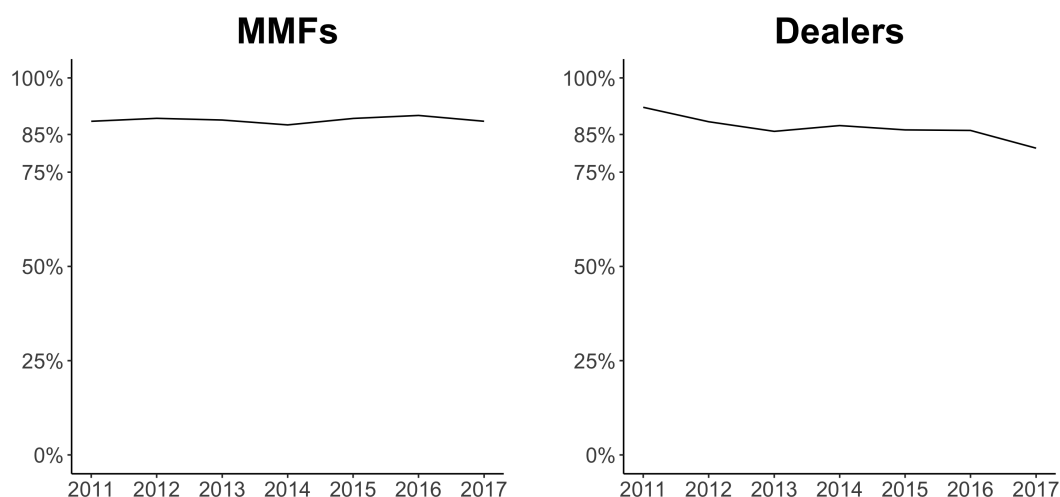
In Variations 3 and 4 of Appendix Table A3, I re-calculate the counterfactual equilibrium in Scenario #2 using Treasury yield sensitivities that are 1 standard error away from the point estimate in Greenwood et al. (2015). The Treasury yield sensitivity in Variation 3 is 48.97 bps for 1 percentage point change in  $\frac{\Delta Treasury}{GDP}$ . The corresponding counterfactual median Triparty repo rate is on average lower than in the original (Variation 0). The Treasury yield is lower in this variation because of higher sensitivity to cash inflow, and the borrowers take advantage and expand their market power. Conversely, when the Treasury yield is less sensitive: at 28.27 bps in Variation 4, the median Triparty repo rate is higher because borrowers cannot extract as large a markdown. Hence, although the standard error around the Treasury yield sensitivity is large (10.35 bps), changing



this sensitivity does not materially change the counterfactual results. Because the counterfactual inflow from the RRP to Treasury is immense, it is important to recognize that Treasury yield is a market equilibrium outcome and can – and should – respond to inflows and outflows. At the same time, the estimation error in the magnitude of the Treasury elasticity does not significantly alter the conclusion of the counterfactual analyses.

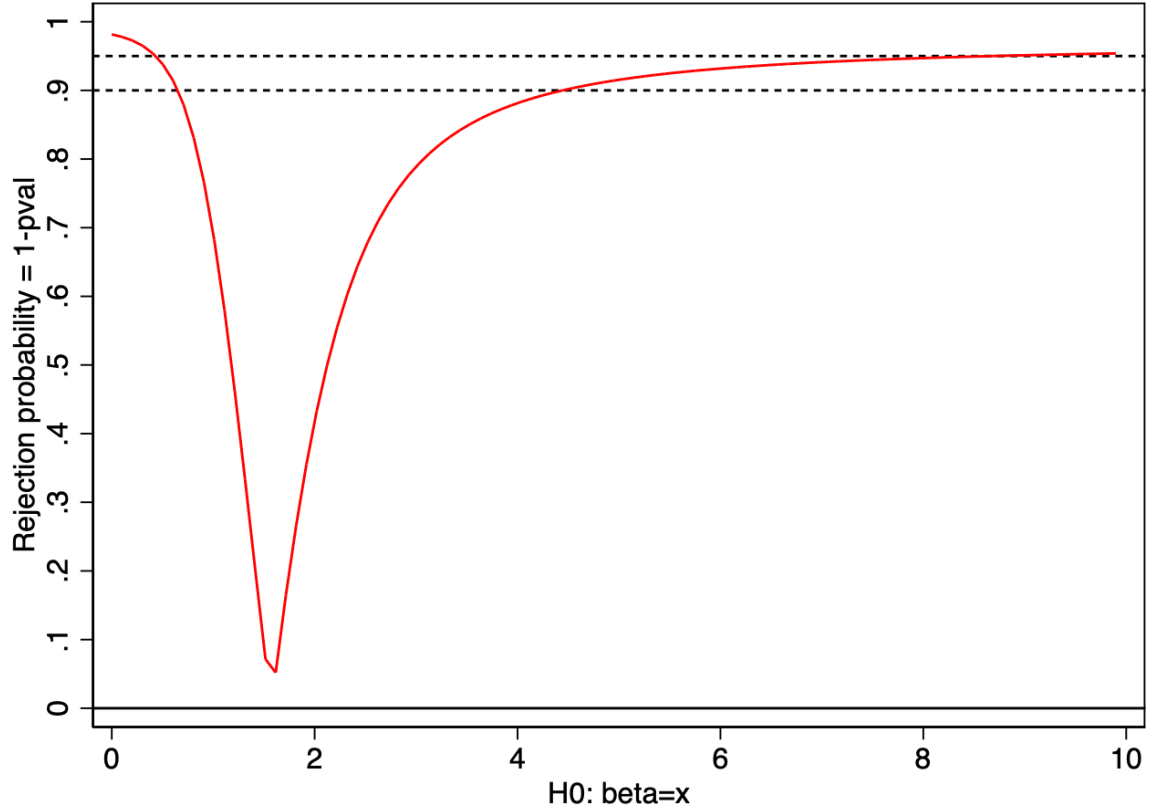
## B Additional Figures and Tables

Figure A1: Percentage of overnight repo market represented by top 18 MMFs and top 20 dealers in the sample



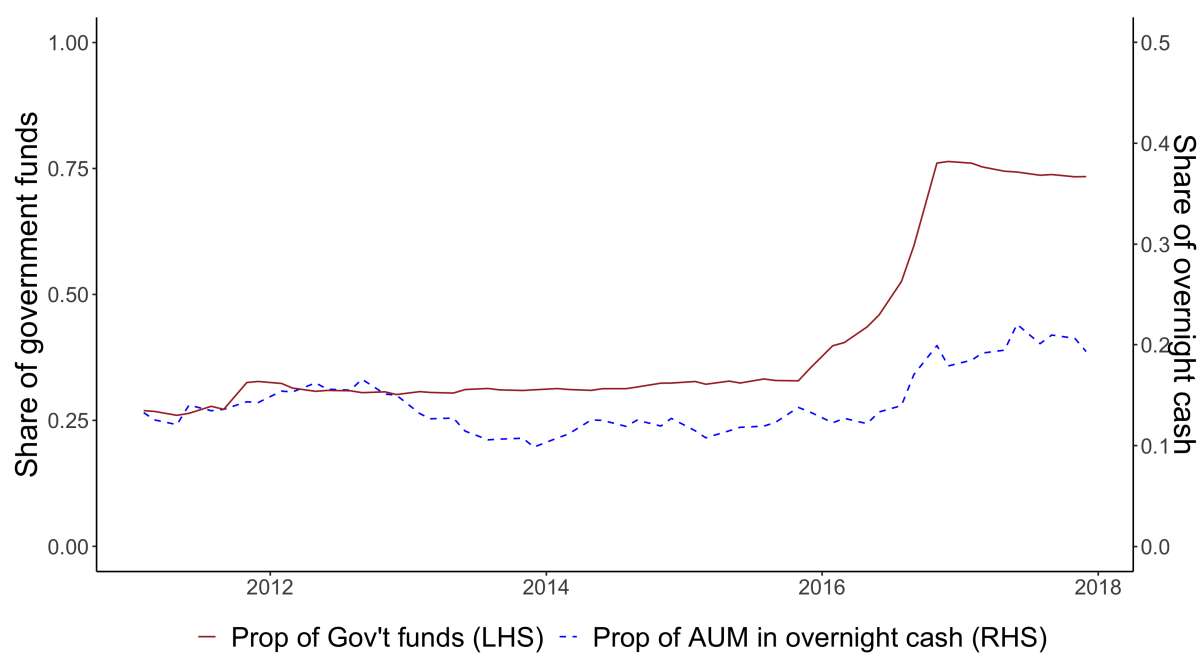
*Notes:* This figure plots, on the left, the share of overnight repo done by the top 18 money market fund families relative to all overnight repo done by money market funds that filed N-MFP reports between January 2011 through December 2017. Plotted on the right is the share of overnight repo done by the top 20 dealers relative to all dealers based on money market funds' N-MFP reports from January 2011 through December 2017.

Figure A2: **Anderson-Rubin test of instrumental variable estimate**



*Notes:* This figure plots the Anderson-Rubin rejection probability for the null hypothesis that the true  $\beta_{IV}$  equals to a given value on the x-axis.  $\beta_{IV}$  is estimated from  $\log(R_{jt}) - \log(R_{zt}) = \beta_{IV}\widehat{vol}_{jt} + BorrowerFE + YearFE + e_{IV,jt}$  in the model estimation period of January 2011 to December 2017, excluding September 2013 through September 2014 when RRP was first introduced and was in testing, and excluding months that fall on quarter ends. The horizontal dashed lines are at  $y = 0.9$  and  $y = 0.95$ . The points where the solid red line crosses the dashed lines represent, respectively, the end points of the Anderson-Rubin 90% confidence interval and 95% confidence interval for the null hypothesis.

Figure A3: **Share of MMF AUM in Government Funds and in Repo**



*Notes:* This figure plots in solid red and against the y-axis on the left, the proportion of MMF AUM in government funds. This figure plots in dashed blue and against the y-axis on the right, the share of total AUM that is overnight cash, measured as lending via overnight repo to dealers and to the RRP.

Table A1: **Borrowers' demand elasticity and  
markdown**

Borrower	Elasticity (%)	Average markdown (bps)
Bank of America	3.2	28.1
Barclays	3.4	26.1
BNP Paribas	3.1	30.6
Citi	5.2	19.0
Crédit Agricole	2.9	33.7
Credit Suisse	4.4	20.2
Deutsche Bank	3.2	25.4
Goldman Sachs	8.3	11.6
HSBC	5.1	19.1
JP Morgan	5.0	18.0
Mitsubishi	5.8	18.7
Natixis	2.5	43.5
Nomura	1.7	56.9
Nova Scotia	6.5	18.2
Royal Bank of Canada	7.4	13.3
Royal Bank of Scotland	4.5	18.0
Société Générale	3.8	26.5
Sumitomo	2.6	40.5
UBS	6.0	14.5
Wells Fargo	2.8	32.3

*Notes:* This table reports two calculated borrower-specific values as discussed in Section 5.5. “Elasticity” shows the percentage volume a borrower would attract if she raises her repo rate by 1 bp. “Average markdown” shows in basis points the time-series average of a borrower’s markdown. Based on parameters estimated in the model estimation period of January 2011 to December 2017, excluding September 2013 through September 2014 when RRP was in testing, and excluding months that fall on quarter ends.

Table A2: **Borrower sensitivity to value of funds**

	1st stage: $vol_{jt}$	IV: $R_{jt}-R_{zt}$	OLS: $R_{jt}-R_{zt}$
Indicator: post 2016 Oct	2.130*** (0.637)		
Vol_jt (fit)		-0.610*** (0.226)	
Vol_jt			-0.005 (0.031)
Borrower FE	Yes	Yes	Yes
Effective F-stat	11.187		
Num. obs.	293	293	293

Standard errors in parentheses.

*Notes:* This table reports the instrumental variable estimate of borrower's sensitivity to value of funds. In the first-stage regression, borrower's total overnight repo volume is regressed on the indicator for post-2016 October. In the IV regression, the difference between borrower's repo rate and the outside option is regressed on borrower's overnight repo volume, as instrumented using first-stage. The OLS regression regresses borrower's repo rates on volume, without using an instrument. Borrower's repo rate is defined as the volume-weighted average of repo rates between a borrower and all lenders in overnight repo collateralized by Treasury securities with 2% haircut. The outside option is defined as the RRP rate. The estimation period is from October 2015 to October 2017, the one year before and after October 2016, excluding months that fall on quarter ends. Standard errors are robust to heteroskedasticity. \*, \*\*, and \*\*\* denote significance levels at 10%, 5%, and 1% confidence levels.

Table A3: Counterfactual sensitivity for scenario #2  
(no RRP, Treasury yield adjusts)

Variation	Triparty repo rate change	Markdown change	Treasury yield change
0. Original	↓ 15.3	↑ 7.6	↓ 11.1
1. Borrower marginal value <i>more</i> sensitive to volume (↑ $\zeta$ )	↓ 16.6	↑ 7.1	↓ 12.0
2. Borrower marginal value <i>less</i> sensitive to volume (↓ $\zeta$ )	↓ 12.9	↑ 8.3	↓ 9.4
3. Treasury yield <i>more</i> sensitive to volume	↓ 16.2	↑ 8.1	↓ 12.5
4. Treasury yield <i>less</i> sensitive to volume	↓ 14.1	↑ 6.9	↓ 9.3

*Notes:* This table reports the counterfactual estimates under different assumptions for the Scenario “2. No RRP, historical Treasury yield”. In this scenario, between 2014 and 2017, lenders see realized 1-day Treasury yield instead of the RRP rate as the outside option to lending to borrowers via overnight repo. Variation 0, “Original”, is as reported in Table 9; specifically, the sensitivity of borrower’s marginal value to volume,  $\zeta$ , is  $1.98 \times 10^{-3}$ , and the sensitivity of Treasury yield to volume is 38.62 bps per p.p. change in  $\frac{\Delta T_{treasury}}{GDP}$ . Variations 1 and 2 consider  $\zeta \pm 1$  standard error, at  $2.71 \times 10^{-3}$  and  $1.25 \times 10^{-3}$ , respectively. Variations 3 and 4 consider Treasury yield’s sensitivity  $\pm 1$  standard error, at 48.97 bps and 28.27 bps, respectively. “Triparty repo rate change”, “Markdown change”, and “Treasury yield change” refer to the time series average of the difference between the historical and the median counterfactual repo rate, borrower’s markdown, and the 1-day Treasury yield, respectively. All numbers are in basis points. Based on parameters estimated in the model estimation period of January 2011 to December 2017, excluding September 2013 through September 2014 when RRP was in testing, and excluding months that fall on quarter ends.