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March 2016

Abstract

We use a new panel data set on intraday transactions of triparty repos (TPR) to study trading relationships in the over-the-counter market. We test the prediction that search frictions lead to relationship formation. We find that TPR trading parties form relationships with a broad number of counterparties but tend to focus their transaction volumes on only a small set of counterparties. We also find that having stable relationships and broader interactions across other funding markets positively shapes the relationships of investors with dealers in the TPR market. Finally, our results suggest that relationships affect the likelihood of a trade and terms of trade and help buffer demand and supply shocks to liquidity. Specifically, the Fed's Reverse Repurchase (RRP) exercise draws funds away from lenders in the TPR market, effectively generating a negative shock to the supply of funds for dealers. Meanwhile, Treasury auctions introduce a positive shock to the demand for funds by dealers. We find that in both cases, shocks are absorbed better by trade partners with stronger relationships.

JEL Classifications: G12, G24, E58
Key words: Triparty repos, OTC markets, trade relationships, RRP exercise, Treasury Auctions, search frictions

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1 Introduction

In an over-the-counter (OTC) market, buyers and sellers search and meet to bargain over the terms of trades. A vast range of securities, including most fixed-income instruments and derivatives, are traded through this trading mechanism instead of centralized platforms, such as exchanges or auctions. Theoretically, it is well recognized that search frictions affect investor behavior and trade outcomes in these markets (Duffie, 2012). Particularly, one important implication of search frictions is that trading parties may form stable relationships to mitigate the effect of search frictions, being driven by either search costs or asymmetric information. Empirically, recent studies document an important role of trading relationships in various OTC markets, including, for example, the interbank markets where banks trade unsecured claims on their excess reserves (Ashcraft and Duffie, 2007; Cocco et al., 2009; Afonso et al., 2014), money market fund lending (Chernenko and Sunderam, 2014), and dealer-intermediated fixed-income trading (Li and Schurhoff, 2014; Hendershott et al., 2015; Di Maggio et al., 2015).

In this paper, we study the quantitative importance of trading relationships in an OTC market for secured claims—the U.S. triparty repo (TPR) market. The TPR market, worth about $1.6 trillion as of September 30, 2015, is a major funding platform for securities dealers, which borrow cash to fund portfolios of securities, and an important investment vehicle for cash investors, such as money market mutual funds (MMFs) and securities lenders. Unlike dealer-intermediated OTC markets - such as those for corporate bonds - investors and dealers trade directly with each other in the TPR market. In contrast to the interbank markets that trade unsecured claims, TPR transactions are effectively secured by mostly high-quality collateral, such as Treasury securities, mitigating the concerns about asymmetric information on counterparty credit risk (Mills and Reed, 2008; Infante, 2015; Hu et al., 2015). In addition, participants in the TPR market are generally large, sophisticated, and well-known financial institutions. Thus, the cost of locating a given trade partner and setting up the related contractual infrastructure should be relatively small. In this context, is there still a role for trading relationships in the TPR market? If so, how are the relationships formed? How do trading relationships affect terms of trade and, in particular, mitigate liquidity shocks?

Taking advantage of a new dataset covering TPR transactions over the period from September 2012 to June 2015, we shed light on these questions by examining trading relationships between MMFs and securities dealers, which are key participants in this market. First, we find that trade parties, particularly larger ones, form stable relationships with a broad set of counterparties but tend to concentrate their transactions on far fewer ones. Speaking to the breadth of trading relationships, the TPR trade volume of MMFs, that only have a trading relationship with one dealer, is only 11 percent of the overall TPR volume in our sample. For dealers, this number is less than 1 percent. Therefore, MMFs typically trade with multiple dealers and vice versa. Indeed, an average investor forms 4 relationships, whereas an average dealer forms 12. Regarding the strength of trading relationships, we adopt the commonly used approach to measure the strength of a relationship between a MMF and a dealer by the concentration of the MMF's total lending to the dealer or the concentration of the dealer's total borrowing from the MMF (see, for example Petersen and Rajan (1994); Ashcraft and Duffie (2007); Afonso et al. (2014)). So, the higher the concentration, the stronger the relationship. We find that while maintaining trading with a broad set of counterparties, trade parties tend to allocate greater volumes to some "preferred" ones. In addition, "preferred" counterparties and relationships are stable over time, in that relationship formation depends positively on their previous dependence in the same market, a result in line with Copeland et al. (2012).

Second, we find that, for investors, the strength of trading relationships in the TPR market depends positively on the overall interactions across other business areas in the lender-borrower pair, suggesting economies of scope in relationship formation. Our test in this regard is motivated by the relationship bank lending literature, which suggests that search frictions can be mitigated by increasing the scope of interactions across different products and over time (see, for example, Petersen and Rajan (1994)). The TPR market is dominated by a few large MMFs and dealers who may interact in multiple businesses. MMFs invest not only in repos, but also in other instruments, such as commercial paper (CP) and certificates of deposits (CDs), that dealers intermediate or issue. As such, investors may form stable relationships in the TPR market if it helps them achieve their overall strategic complementarity across markets and overall profitability. Our results support this prediction, as we find that MMFs with larger overall lending to a specific dealer across various markets form a stronger relationship with that dealer in the TPR market.

Our finding of economies of scope in trading across markets for MMFs may help reconcile the seemingly contradictory results in previous TPR studies. Specifically, on the one hand, Hu et al. (2015) and Copeland et al. (2014) find that the creditworthiness of the borrower (dealer), as measured by the dealer's CDS does not affect the terms of TPR trades.[1] On the other hand, Copeland et al. (2014) find that the identity of the borrower does matter for terms of trade. Our results suggest that one channel through which the dealer's identity matters is that it represents the scope of interactions with lenders. In the context of such broad interactions, higher credit quality may not appear to matter because it is already one of the factors that lenders take into account when forming the trading relationship.

Finally, we find that trading relationships affect terms of trades and, importantly, help absorb shocks to both the demand for and supply of liquidity in the TPR market. Previous theoretical studies suggest that stronger relationships reduce search costs and increase ability to withstand liquidity shocks (Duffie et al., 2005, 2007; Vayanos and Weill, 2008; Weill, 2008; Lagos and Rocheteau, 2009). Empirical results in the federal funds market support these theoretical predictions (Ashcraft and Duffie, 2007; Afonso et al., 2014). Here we also test the hypothesis that, all else being equal, liquidity shocks would have a milder impact on pairs

[1]Hu et al. (2015) use transactions-level data obtained from the monthly reports of MMFs to the SEC. They examine repo rates (spreads), volumes, and haircuts with respect to collateral types and borrower creditworthiness. In contrast to our daily data, they observe snapshots at month-ends and have only a subset of repo transactions (because not all MMFs report their holdings). They also include quarter-end dates, which contain different pricing dynamics due to regulatory reasons. Their paper is closely related to Krishnamurthy et al. (2014), who find evidence of a run in the TPR market using less refined data (the quarterly reports of the top 20 MMF families (N-CSR, N-CSRS, and N-Q) before the 2010 TPR reform).

with stronger relationships in the TPR market.

We use two types of quasi-natural experiments to identify the effects that shocks to the demand for, and the supply of, repo funding may have on the role of relationships in the TPR market. Our first experiment is Treasury auctions. While primary dealers are the main buyers at these auctions, other securities dealers may also take part in the auctions directly. A key funding source for dealers to purchase Treasury issuance is the TPR market. Thus, a new Treasury auction leads to an exogenous increase in dealers' demand for TPR borrowing. Our second experiment is the Fed's overnight reverse repurchase (ON RRP) operations. As a tool in the normalization of monetary policy, the Fed has been conducting ON RRPs since September 2013. In these operations, the Fed effectively borrows from a selected group of eligible cash investors (ON RRP counterparties), up to a cap at a given offer rate, in the TPR market. Therefore, all else being equal, the introduction of ON RRPs essentially reduced the supply of funds to the private dealers.

In both settings, we find that trading relationships significantly affect the outcome of a trade and, importantly, help absorb liquidity shocks. In terms of shock absorption, when dealers face positive shocks to the demand for repo funding, as needed to fund Treasury auction purchases, the MMFs with stronger relationships with dealers are the ones that fund the larger amounts at more favorable rates for those dealers. As for the supply shocks, we find that the Fed's RRP operations lead to a decline in the supply of funds to dealers. That is, after the ON RRP started, MMFs replaced private repos (repos with dealers) with ON RRP (repos with the Fed). However, MMFs with stronger relationships with dealers tend to be less sensitive to ON RRP terms in that their reduction in lending to dealers is smaller, and they are remunerated for their "loyalty" by marginally higher rates. In that sense, ON RRPs may increase the bargaining power of MMFs, albeit only marginally. In their study on the MMF lending during the 2011 European debt crisis, Chernenko and Sunderam (2014) also find similar relationship effects on the willingness of MMF lending.

Our paper contributes to the nascent quantitative studies on OTC trading mechanism.

To the best of our knowledge, our study provides the first direct analysis of trading relationships in a secured market using transactions data. This contribution is important because trading relationships have been thought of mainly as a tool to mitigate information frictions in the absence of quality collateral (e.g., Sharpe (1990); Boot and Thakor (1994); Boot (2000)). The emerging studies on the OTC trading mechanism have investigated the value of trading relationships in the interbank market, where banks trade excess reserves to meet daily reserve requirements (Ashcraft and Duffie, 2007; Afonso et al., 2014). Related, recent studies have begun to examine the value of relationships from the trading network point of view for market makers in other unsecured markets, such as those for corporate and municipal bonds (Li and Schurhoff, 2014; Hendershott et al., 2015; Di Maggio et al., 2015). In trading unsecured claims, information on counterparty liquidity and credit risk becomes an important consideration in choosing trade partners. For the secured TPR market, Copeland et al. (2014) present suggestive evidence on the existence of stable relationships as part of their analysis on the bank-run behavior in the TPR market during the recent financial crisis. However, due to data limitations, they do not directly measure the stability of the relationship, nor do they provide empirical evidence as to why these relationships exist or how they are structured.

We also extend the existing OTC literature in a new direction, namely that of relationship bundling, by examining the scope for broad relationships in the trading mechanism. Our evidence suggests that there are economies of scope in trading for investors, which determine interactions across markets and shape overall needs for smooth investment. We create an innovative data set by combining TPR transactions data and MMF regulatory reports to examine trading relationships both over time and across markets.

Finally, we provide an innovative approach to examining the role of relationships in mitigating liquidity shocks, namely using Treasury auctions as a quasi-natural experiment for TPR funding demand shocks and ON RRPs as funding supply shocks. Importantly, to the best of our knowledge, we also provide the first study on the effect of the Fed's ON RRP exercise on the TPR market.

The rest of the paper is organized as follows. Section 2 presents a short description of the TPR market. Section 3 motivates our empirical hypotheses. Section 4 discusses our data, sample construction, and the construction of the variables used in our regressions. Section 5 presents our empirical results. Section 6 concludes.

2 Trading Mechanisms in the Triparty Repo Market

A repo is the sale of a security, or a portfolio of securities, combined with an agreement to repurchase at a pre-specified price on a specified future date.[2] Two types of repo transactions make up the broad U.S. repo market. One is the bilateral, or "delivery versus payment (DvP)," market, in which a repo is typically settled when the securities provider delivers the securities to, and simultaneously receives the cash from, the cash provider. The other type of repo is the TPR market, the focus of this paper, in which two clearing banks facilitate the clearing and settlement of repo contracts on their own balance sheets by maintaining cash and security accounts for investors (cash lenders) and dealers (cash borrowers).[3] Investors include cash-rich institutions - a large fraction of which (around 40 percent) are MMFs, the rest being various asset managers; local or state government treasurers; and securities lenders. Securities dealers use the TPR market as a source to fund the securities on behalf of their clients or for their own securities inventories, such as their purchases in Treasury auctions.

Despite the existence of a clearing bank, all TPR transactions and trade agreements are made bilaterally. The clearing banks do not match dealers with cash investors, nor do they

[2] From the accounting point of view, the repo transaction generally does not result in a "sale" of the collateral. While the lender receives the title of the collateral, the borrower continues to receive the economic benefits of the collateral. Moreover, the collateral generally remains on the borrower's balance sheet. See Wiggins and Metrick (2014). See also Copeland et al. (2012) for an extensive description of the U.S. repo market.

[3] The General Collateral Finance market (GCF), a blind-brokered interdealer market, is also part of the triparty market, as GCF repo settlement takes place through the TPR platform. But GCF transactions are not included in our data set and therefore do not enter our analysis.

play the role of brokers in this market. Instead, this bilateral trade mechanism entails search frictions, which may give rise to the role of relationships. Specifically, these search frictions may include the following factors.

First, before any actual transactions, an investor and a dealer who wish to form a trade pair have to find and agree on some general trade framework. This framework takes the form of a contractual trading relationship by entering a Master Repurchase Agreement (MRA). Parties find each other and negotiate some general terms of potential repo trades between them, including, importantly, repo haircuts—the difference between the market value of securities (collateral) and the cash loan amount—and general characteristics of eligible collateral. Although these terms may vary over time, they are not always negotiated on a daily basis, due in part to the costs of revising the MRA.

Second, when it comes to actual trades, parties have to search for a matching counterparty that already has a MRA. MMFs or dealers may sign an MRA with more than one counterparty. However, they may choose not to transact with all the counterparties with whom they have contracted. Each search is costly because it takes time and does not always generate a match: Sometimes, parties cannot agree upon the terms of trade, including the repo maturity, the rate, and repo amount. In addition, it also takes time and resources to establish new MRA contracts (that is, expanding the set of potential trade partners). As shown in Duffie et al. (2005), these search costs imply that the interactions between funds and dealers are deemed to be strategic.

Third, liquidity shocks, which may be private information, can affect search behavior even on a daily basis. Typically, dealers initiate the search early in the morning, with the bulk of repo trades arranged before 10 a.m. However, some deals may be amended later in the day to accommodate intraday liquidity shocks, such as investors' redemption for MMFs (Copeland et al., 2012). The bulk of trades are confirmed by 3:30 p.m, when settlement starts, with additional smaller batches settled continuously thereafter for later trades. Overall, the information asymmetry on liquidity shocks may contribute to search frictions, even if counterparty credit risk is low.

3 Hypotheses

In this section, we motivate the hypotheses tested in our empirical analysis. Our first empirical goal is to examine the quantitative significance of trading relationships in the TPR market. In theory, the strength of trading relationships in a market may reflect the extent of search frictions (Ashcraft and Duffie, 2007). After all, in a frictionless, complete market in which individual traders are price-takers, trade outcomes would not depend on the choice of trade partners. Duffie et al. (2005) and subsequent work - such as Afonso and Lagos (2015) who provide a formulation of the search-based model for the federal funds market - suggest that in the presence of search frictions, bilateral relationships are inherently strategic and reflect each counterparty's alternatives to immediate trade.[4] In addition, network theory suggests that relationships can be generated endogenously in an unsecured OTC market to reduce search frictions induced by information asymmetry (Babus and Hu, 2015).[5]

However, it is an interesting quantitative question whether search frictions may manifest in trading relationships in the TPR market. On the one hand, being generally large, sophisticated, and well-known financial institutions, participants of the TPR market may have low marginal costs in locating a trade partner. Also, the use of high-quality collateral may mitigate the concerns about asymmetric information on counterparty credit risk (Mills and Reed, 2008; Infante, 2015; Hu et al., 2015). On the other hand, various factors imply search frictions may still be significant. The scope of search is limited by costly negotiation and the need for establishing new MRAs outside existing contracts. Also importantly, the collateral in the TPR market may provide a false sense of security. The security of collateral

[4] Among others, Duffie et al. (2007) treat the implications of search frictions for risky asset pricing; Vayanos and Weill (2008); Weill (2008) treat multiple assets in the economy; Lagos and Rocheteau (2009) introduce entry of dealers and a nontrivial choice of asset-holdings.

[5] Intermediaries in the model of Babus and Hu (2015) have the ability to enforce contracts and provide monitoring devices that sustain trade without collateral in cases where trade counterparties meet infrequently. Therefore, forming relationships in the OTC market reduces search and informational frictions and allows access to more favorable terms of trade.

may unravel quickly during times of stress, in part because MMFs, the major cash lenders in this market, are limited by regulations in their capacity to hold long-maturity securities. Thus, in the event of counterparty defaults, MMFs would have to quickly sell the collateral, possibly at fire sale prices.[6] Under such conditions, MMFs may essentially treat repos as unsecured transactions, which in turn implies that the identity of the counterpart matters. These considerations, as well as the suggestive evidence by (Copeland et al., 2014), lead us to hypothesize that trade relationships exist in the TPR market.

We also hypothesize that the formation of trading relationships in the TPR market may depend on the broad interaction between the funds and dealers across markets. The relationship banking literature has extensively documented that counterparties form stable relationships in part to achieve economies of scale in information collection and reduce information asymmetry (Petersen and Rajan, 1994; Ongena and Smith, 2000). Importantly, the scale economies in information can be achieved by observing the borrower over time as well as over products (Petersen and Rajan, 1994; Boot, 2000). Indeed, two main measures of relationship strength in this literature are the duration of the relationship and the scope of the relationship, with the latter defined in terms of the different services offered by the bank and utilized by the firm (Ongena and Smith, 2000). In line with their predictions, we postulate that the formation of trading relationships in the TPR market may depend on the broad relationships between investors and dealers across markets, a strategy that could be motivated by informational gains or overall profit-maximizing considerations. This behavior maybe particularly true for MMFs, who are keenly interested in the quality of their counterparts due to, among others, regulatory reasons.

Finally, we hypothesize that trading relationships facilitate the absorption of liquidity shocks for both sides of the TPR trade. While the banking literature often finds that relationship lending helps reduce asymmetric information concerns over credit risk, the interbank

[6] In distressed conditions, search frictions increase and asset prices are undervalued, especially if additional trade partners are needed (Antinolfi et al., 2015). Indeed, these dynamics explain why MMFs completely withdrew from the repo market in the wake of the Lehman collapse (Copeland et al., 2014; Krishnamurthy et al., 2014).

lending studies find that relationships mitigate the impact of liquidity shocks (Ashcraft and Duffie, 2007; Afonso et al., 2014). In these latter studies, the need of banks to manage optimal excess reserves results in relationship formation among banks with opposite liquidity shocks. Unlike the federal funds market, participants in the TPR market are clearly delineated into borrowers and sellers. So, by construction, the TPR market also involves trades between counterparties with opposite liquidity needs. As such, liquidity supply and demand can vary both over time and across agents, leading to a mismatch in the amount of needs of any fund-dealer pair. This matching process involves searching, transaction costs, and possible information asymmetry on either counterparty credit risk or liquidity shocks. Therefore, we postulate that trading relationships help mitigate liquidity shocks in the TPR market. Our innovation is that to identify the role of trading relationships, we explore quasi-natural experiments based on Treasury auctions and the Fed's ON RRPs exercises as proxies for shocks to the liquidity demand and supply, respectively.

4 Data, Sampling, and Variables of Interests

4.1 Data and Sampling

Our main data set consists of all transactions in the U.S. TPR market, including those involving the Federal Reserve but excluding GCF, from September 2012 to April 2015. The sources of these transactions are confidential reports by the two clearing banks, the Bank of New York Mellon (BNYM) and J. P. Morgan Chase (JPMC). We sample transactions on the same day each week throughout the period. As a result, throughout the paper, monthly statistics in fact account for only the selected weekdays in our sample. Both banks reported the same set of fields, including the date of trade, the names of the investor and the dealer, repo quantity, rate, maturity, collateral type, and a flag for an open trade.[7]

[7]These reported fields are the 13 minimum parameters required for TPR matching, as determined by the TPR Reform Task Force. Information on haircuts or specific CUSIPs of collateral is not among the required fields and is not included in these reports.

We apply the following filters to construct our research sample. First, we restrict our analysis to transactions with overnight (including open trades) Treasury repos. This leads to a more homogeneous sample and allows us to better identify the effect of trading relationships by reducing the influence of factors (such as collateral quality) for which we may not have sufficient information to control. On an average day, about 90 percent of the TPR trades are overnight, of which about 50 percent are Treasury repos (in dollar amount). We also exclude quarter-ends from the analysis to limit seasonal effects on our results.[8]

Second, we focus on MMF investors only. We apply this restriction for two reasons. One, among the several main types of investors in this market, we can identify only MMFs with confidence and can obtain sufficiently rich information about the investor characteristics, including fund family names for necessary aggregations.[9]. Two, MMFs are a major investor in the TPR market and previous literature has also focused on their behavior (Hu et al., 2015; Krishnamurthy et al., 2014).

Third, we include in our sample only the top dealers and MMFs ranked by total transaction volumes at the dealer-parent and the fund-family level, respectively. There are 31 dealer parents and 73 fund families in our sample. For each month, we rank dealer parents and fund families based on their repo volumes over the previous month and keep the top 15 dealer parents and the top 40 fund families—a sampling approach similar to that by Ashcraft and Duffie (2007); Afonso et al. (2014). These top MMFs and dealers account for almost 99 percent of all transactions. So this filter is not restrictive at all, mainly removing those TPR participants with rather sparse activities.

For each fund family, we group its funds into two subfamilies according to whether a fund

[8]Munyan (2015) documents the quarter-end seasonality in the TPR market. Specifically, European dealers tend to shrink their balance sheets at quarter-ends to reduce their asset base used for leverage ratio calculations. Because we sample one day of observations each week, there are only three quarter-ends in our sample.

[9]The raw data contain names of investors and dealers but no unique identifier for them. To identify MMFs, we first use string matching techniques to select investor names that contain MMF-related keywords (such as “money market mutual funds,” “cash equivalent,” and “liquidity fund”). We then crosscheck our selection using the MMF names reported in the SEC Form N-MFP—a monthly filing by MMFs on their holdings of individual securities at month-ends. Overall, we managed to identify almost 80 percent of the MMFs’ overnight Treasury repo volume reported in the SEC N-MFP data at month-ends.

is an ON RRP-eligible counterparty. Eligible counterparties are those lending funds for whom the data indicate that the borrowing dealer is the Federal Reserve. We conduct our analysis at the dealer-parent and fund sub-family (hereafter, "dealer" and "fund," respectively) level. In our sample, RRP-eligible MMFs belong to 26 different families, all but two of which also have funds that are not eligible. Within each subfamily, we aggregate the repo volumes on each day and calculate the average repo rate, weighted by the volume of each trade on that day.

Finally, we combine information from a few other sources. Specifically, we use information in the SEC's Form N-MFP on repos and other asset holdings to construct measures for broader relationships (see details in Section 4.3). Also, we use data on RRP operations provided by the New York Fed to study the effect of RRP-induced liquidity shocks.

Furthermore, we use public data on Treasury auctions, including aggregate allocated amount on Treasury notes and bonds.

4.2 Sample Statistics

Our final sample includes 21 unique dealer parents and 63 unique fund subfamilies, among which there are about 23,500 trades during the sample period, which is close to one fourth of all the potential trades that would have occurred, had each fund transacted with every dealer on each day. (Recall that we aggregate all transactions between a dealer–fund pair on a given day and treat them as one trade.) On average, total daily trade volume is about \$150 billion. As shown in Table 1, the average trade has a volume of \$0.44 billion at a repo rate of 7 basis points (bps).

We use each participant's transaction volumes as a proxy for their relative sizes, following a methodology similar to Ashcraft and Duffie (2007). Specifically, let us denote the amount of repo trades between fund i and dealer d at time t by $V_{i,d,t}$, and the number of funds and dealers by N_f and N_d, respectively. Then, the size of a fund i at t, denoted by $IV_{i,t}$, is defined as

$$IV_{i,t} = \sum_{s=t-1}^{t-c} \sum_{d=1}^{N_d} V_{i,d,s}, \tag{1}$$

where t is the current day of the month, $t-1$ is the previous day, and $t-c$ is the same day of the previous calendar month. That is, we estimate the size of a fund using the total amount of repos lent by the MMF to all dealers over the previous "rolling month." For example, if today is December 30, the rolling month would be from November 30 until December 29. Note that because we include only one trade day per week, a rolling month effectively consists, on average, of four days. Similarly, the size of dealer d at t, denoted by $DV_{d,t}$, is estimated by the total repo dollar volumes borrowed by dealer d from all funds over the previous rolling month. That is,

$$DV_{d,t} = \sum_{s=t-1}^{t-c} \sum_{i=1}^{N_f} V_{i,d,s}. \tag{2}$$

Table 1 presents summary statistics on size. As shown in column (1), on average, a fund (that is, a sub-fund-family defined above) lends about \$16 billion of overnight repos, and a dealer borrows about \$27 billion, over a month. Thus, given that both the standard deviations of both the fund size and the dealer size are similar, at about \$17 billion (column (3)), the fund size is relatively more dispersed. Roughly speaking, the fund size is also more skewed, as its median, at about \$9 billion, is just over half of its mean, while the median of the dealer size is only somewhat lower than its mean.

There is also a wide range in both MMF and dealer sizes. For example, among the fund families that are ranked monthly as the largest (Rank 1), their subfamily funds (defined above) lend on average \$45 billion a month, with a standard deviation of \$24 billion.[10] In contrast, among the fund families that are ranked monthly as the smallest (Rank 40), their subfamily funds lend on average only a quarter billion dollars a month, with a standard

[10]Note that while the overall triparty repo market may be concentrated, the fund families and dealer parents that we ranked as number one in the overnight Treasury segment have changed from month to month in our sample.

deviation of less than one-fifth billion dollars. Similarly, among the dealer parents that are ranked monthly as the largest (Rank 1), they borrow on average just over \$50 billion a month, with a standard deviation of just over \$10 billion. In contrast, among the dealer parents that are ranked monthly as the smallest (Rank 15), they borrow just \$2.5 billion a month, with a standard deviation of \$2 billion.

4.3 Measuring Trading Relationships

To measure trading relationships in the TPR market, we again follow a methodology similar to Ashcraft and Duffie (2007). From the MMF i's point of view, the strength of its relationship with dealer d is the dollar volume of repos that the fund lends to the dealer over the previous rolling month divided by its total amount of repo lending to all dealers in the month. In other words it measures the concentration of the MMF's lending to a specific dealer over a relatively long period. The strength of a dealer's relationship with a fund is defined accordingly. To be precise, denote the fund-dealer and the dealer-fund relationship strength by $RS^{i}_{i,d,t}$ and $RS^{d}_{i,d,t}$, respectively. Then,

$$RS^{i}_{i,d,t} = \frac{\sum_{s=t-1}^{t-c} V_{i,d,s}}{IV_{i,t}}; \qquad RS^{d}_{i,d,t} = \frac{\sum_{s=t-1}^{t-c} V_{i,d,s}}{DV_{d,t}}. \tag{3}$$

By construction, these relationship-strength measures range between zero and unity. The higher the value, the stronger the relationship.

We also define relationship formation variables as follows:

$$RF^{i}_{i,d,t} = \frac{V_{i,d,t}}{\sum_{d=1}^{N_d} V_{i,d,t}}; \qquad RF^{d}_{i,d,t} = \frac{V_{i,d,t}}{\sum_{i=1}^{N_f} V_{i,d,t}}. \tag{4}$$

That is, $RF^{i}_{i,d,t}$ is the fraction of fund i's total reverse repo volume at t that is lent to dealer d. In other words, $RF^{i}_{i,d,t}$ measures how fund i distributes its current investments among the various dealers. Roughly speaking, $RF^{i}_{i,d,t}$ indicates whether a fund strengthens or weakens its existing relationship with a dealer, which is suggestive of how it chooses to form relationships. The same interpretation applies to $RF^d_{i,d,t}$.

Finally, we construct variables, which we refer to as "broad relationships," to proxy the trading relationships between an MMF and a dealer across two broad sets of markets. The first one measures the relationship strength in other TPR markets, i.e. trading of repos outside the triparty overnight, Treasury collateral space (in essence, this includes longer maturities and different types of collateral). We obtain the volumes of these repos using the Form N-MFP data as previously described. The second one measures the relationship strength of MMFs and dealers using transactions of other money market claims between a fund and a dealer, including CP (consisting of financial commercial paper and asset-backed commercial paper) and CDs.[11]

For each of these two broad sectors, the logic to define broad relationship strength is in line with the RS^i and RS^d measures previously discussed. From the MMF i's point of view, the strength of its relationship in other repo markets with dealer d is the dollar volume of repos in other repo markets that it lends to the dealer over the previous rolling month divided by its total amount of repo lending in those markets over the previous month. Similarly, the strength of MMF i's relationship in CP and CD markets with dealer d is the dollar volume of CP and CD that the MMF invested with a dealer over the previous rolling month divided by its total amount of CP and CD invested over the previous month. A similar logic applies for the dealer-investor relationships. To be precise, we define Broad Relationship Strength (BRS) as follows:

$$BRS^i_{i,d,t} = \frac{\sum_{s=t-1}^{t-c} Holdings_{i,d,s}}{\sum_{s=t-1}^{t-c}\sum_{d=1}^{N_d} Holdings_{i,d,s}}; \qquad BRS^d_{i,d,t} = \frac{\sum_{s=t-1}^{t-c} Holdings_{i,d,s}}{\sum_{s=t-1}^{t-c}\sum_{i=1}^{N_f} Holdings_{i,d,s}}, \tag{5}$$

where the *Holdings* variable measures either the "other repo" trade volume or the trade volume of "CP and CDs." Recall that the Form N-MFP data are available for only month-ends. So we carry the same values over all trading days in the previous month.

[11]We treat the program sponsors as "the issuer" in the ABCP conduits.

5 Results

In this section, we first present the results from a descriptive analysis on the strength and formation of trading relationships in the TPR market, followed by an analysis on the determinants of relationship formation. We then examine the value of trading relationships from three different angles: the effect of relationships on the likelihood of a trade and terms of trade, the role of relationships in buffering shocks to the supply of funds due to the Fed's RRP exercises and shocks to the demands for funds due to Treasury auctions.

5.1 Univariate Analysis of Trading Relationships

We have learned from the previous section that out of all possible trade pairs between funds and dealers in our sample, only around one fourth execute actual trades. Table 2 provides additional characteristics on these trades from the point of view of relationship strength and formation.

A few points are worth noting. First, actual trades are a relatively small percentage of all possible trade combinations, and this is particularly true for smaller counterparts compared with larger ones. As shown in the first column of Table 2, on average, a given fund lends to just over one fourth (or about four) of the potential borrowers over a month; similarly, a given dealer borrows from a touch shy of one fourth (or about 12) of funds (in terms of subfund families) of the potential lenders. Comparing the top size rank (ranked first) and the bottom size rank (ranked fifteenth for dealers and ranked fortieth for investors), we find that larger investors and dealers are more likely to have trading relationships with more counterparts: On average, the largest (ranked first) fund builds trading relationships with about half (or eight) of potential borrowing dealers over a month, while the smallest (ranked fortieth) fund builds trading relationships with only one-tenth (or about two) of potential dealers. Similarly, the largest dealer has trading relationships with about 43 percent (or 30) of funds over a month, while the smallest dealer has trading relationships with 6 percent (or four) of the funds. The same pattern holds in terms of relationship formation and for broader relationships as well, only with different magnitudes.

Second, conditional on having trading relationships, both relationship strength and formation are fairly concentrated, particularly so among smaller funds and dealers. The conditional average strength values for both funds and dealers all fall below one, suggesting that the relationships among trading partners are not exclusive (for example, a unique counterpart is a very rare occurrence). Specifically, Table 2 (column 2) suggests that MMFs tend to lend, on average, only 26 percent of their total volumes to a specific dealer over a month, and for dealers, the number is even lower, at under 10 percent. However, the medians (column 3) of the respective variables are all smaller than their means, suggesting that relationship strength is skewed to the right. That is, relationships are concentrated among a relatively small set of counterparties. A similar pattern holds for relationship formation as well as for the broader relationship strength variables (in other repo markets and in CP and CD markets).

To see further how relationship strength varies with size, we plot in Figure 1 the average relationship strength variables by the size ranking of the dealers and investors. As shown, the relationship strength for both funds and dealers is decreasing with their respective sizes (increasing with rank). This finding is consistent with Copeland et al. (2014), who, based on more aggregate data, find that smaller dealers (investors) tend to form more concentrated relationships (that is, they borrow (lend) from fewer investors (dealers)). Our finding is also similar to the interbank results (Furfine, 1999; Afonso et al., 2014), which find that small banks choose to form more concentrated lending relationships than large banks. Similar results are found in the dealer-intermediated OTC markets (see, Li and Schurhoff (2014); Hendershott et al. (2015); Di Maggio et al. (2015)).

Finally, we find that both funds and dealers, especially funds, form stable and relatively stronger relationships with a small subset of trade partners. To see this, we estimate cumulative relationship strength measures using all transactions over the entire sample period, which we call Long-Term Relationship Strength (LTRS). The distributions of these LTRS measures are in Figure 2. Intuitively, LTRS is calculated using the same formula as our RS variable, except that both denominator and numerator are aggregated across the whole sample. We do this in order to capture the strength of "lifelong" and therefore stable relationships. For example, the first bar in Panel A shows the distribution of all dealers' cumulative LTRS with their top-ranked investors, the second bar shows the distribution of all dealers LTRS for the top two investors, and so on. Similar logic holds for Panel B.

The figures suggest that both dealers and investors have traded with a number of partners over the sample period. However, as shown in Panel A, a typical dealer (in terms of median) obtains close to 40 percent of its "lifelong" funds from its top lending fund and just short of 60 percent from its top two funds. Transactions with its top five funds provide almost 80 percent of its funds. As shown in Panel B, a typical fund (again in terms of median) invests 60 percent in its funds to its top borrowing dealer, whereas the top two dealers take nearly 90 percent of its lending. Because the relationships and ranking are estimated using the entire sample period, the concentrations also suggest that these relationships are stable over time. In the next section we will give additional qualifications on the stability of relationships and its ability to absorb liquidity shocks.

5.2 The Determinants of Relationship Formation

We now examine further the determinants of relationship formation using a multivariate regression approach. So far, descriptive evidence suggests that, consistent with findings in previous literature on interbank markets, larger funds and dealers trade with a greater set of counterparties, compared with smaller ones. However, trading relationships typically tend to be focused on a small set of trade partners with whom they are also stable over time. Thus, we hypothesize that relationship formation is positively related to fund and dealer sizes and the strength of existing relationships. Moreover, we have already hypothesized that relationship formation in overnight Treasury TPR trading may depend on relationships in broad markets that the parties interact with.

Our empirical method is the following. Recall that, on any given t, we first form potential trade pairs between all dealers and subfund families in our sample.[12] Then, we adopt a joint probit and OLS approach to estimate the following empirical models:

$$Y_{i,d,t} = f\left(\mathrm{IV}_{i,t}, \mathrm{DV}_{d,t}; \mathrm{RS}^{i}_{i,d,t}, \mathrm{RS}^{d}_{i,d,t}; \text{Broad relationship}; \text{Fixed effects}\right) + \epsilon_{i,d,t}, \tag{6}$$

where, in the case of the probit model, $Y_{i,d,t}$ is a dummy that takes the value of one when either $\mathrm{RF}^{i}_{i,d,t}$ or $\mathrm{RF}^{d}_{i,d,t}$ are positive. The probit model is run on the full sample of all potential trades. In the case of the OLS model, $Y_{i,d,t}$ is either $\mathrm{RF}^{i}_{i,d,t}$ or $\mathrm{RF}^{d}_{i,d,t}$. The OLS model is run on a restricted sample, conditional that a relationship is formed. As noted in Section 4.3, IV and DV are proxies for the sizes of MMFs and dealers, respectively, and RS^{i} and RS^{d} are the relevant relationship strength variables, accounting for the existing relationships. "Broad relationship" variables are relationship strengths (BRS) formed in two broader types of trades among counterparties: In repo trades other than overnight Treasury ones and trades in the CP and CD markets. Finally, we use fixed effect variables to control for unobservable heterogeneity at the dealer parent, fund family, and macroeconomic levels.

The regression results are presented in Table 3. The table presents the coefficients of the factors affecting the likelihood of relationship formation (columns 1 and 3) and, conditional on forming a relationship, the strength of relationship formation (columns 2 and 4) for both investors and dealers.

A few findings are worth noting. First, as we expected, the likelihood of relationship formation for investors increases with investor sizes. All regressions of $RF^{i}_{i,d,t}$ and $RF^{d}_{i,d,t}$ show a positive coefficient, which, in most cases, is also statistically significant. Thus, all

[12] To this end, we pair up all funds (at the subfamily level) and dealers (parents) to form the sample of potential trades. For example, there could be (at most) $15 * 80 = 1200$ potential trades on a given day if all top 40 MMF families identified in that month have both RRP-eligible counterparty funds and ineligible funds (so each family has two subfamilies) and transact with all 15 dealers. In our data, the number of potential trades varies each month, based on whether the top MMF families identified for this month have eligible and non-eligible funds.

else being equal, larger funds (dealers) tend to form more relationships. As a consequence, conditional on a relationship being formed, larger funds and dealers have more dispersed relationship outcomes. The negative, statistically significant OLS coefficients for IV and DV confirm this point.

Second, for both investors and dealers, the likelihood and strength of relationship formation in the overnight Treasury TPR trades depend strongly and positively on their existing relationship strength. All coefficients of $\mathrm{RS}^i_{i,d,t}$ and $\mathrm{RS}^d_{i,d,t}$ in regressions of $\mathrm{RF}^i_{i,d,t}$ and $\mathrm{RF}^d_{i,d,t}$, respectively, in both probit and OLS models are positive and statistically significant. Moreover, the OLS coefficients, respectively, are around 0.8 or above, with those of dealers being slightly greater. The probability of forming a relationship is also enhanced by previous relationships. These results, support the reasoning of Figure 2 and confirm that relationships are reinforced over time and are stable.

Third, for investors, the likelihood and strength of relationship formation in the overnight Treasury TPR market depends positively on their BRS with a given dealer, while the opposite holds for dealers. In the $\mathrm{RF}^i_{i,d,t}$ regressions, the coefficients of $\mathrm{BRS}^i_{i,d,t}$ for both other repos and CP and CDs are all positive and statistically significant, although the magnitudes are smaller than their dependence on the overnight Treasury TPR trades. Thus, an average investor is more likely to form a relationship and, once the relationship is formed, an average investor tends to allocate larger fractions of their funds to dealers with whom she has relatively stronger relationships in other markets. This result may suggest that MMFs "learn" about their dealers in multiple markets.

Interestingly, for dealers, the results appear to be the contrary. The regressions of $\mathrm{RF}^d_{i,d,t}$ produce negative and statistically significant coefficients of $\mathrm{BRS}^d_{i,d,t}$ for CP and CDs. So, it seems that dealers who tend to fund relatively more in CP and CD markets from specific investors, have less recourse to these investors in the overnight Treasury TPR market. In other words, dealers tend to trade less and, once a trade occurs, tend to allocate a smaller fraction of their borrowing to those investors who account for a relatively larger fraction of the dealers' funds in markets outside of the overnight Treasury TPR trades. Turning our attention to the remaining repo market, the higher is the funding that dealers obtain in the remaining TPR market, the lower the likelihood of forming a relationship in the overnight Treasury TPR market. However, once a relationship is formed, broader TPR relationships affect positive ON Treasury ones.

5.3 The Value of Relationships

We now turn to the value of relationships in the TPR market. Our approach is to first study how relationships may affect the likelihood of a successful trade and the terms of trade and then to study how relationships may help absorb shocks to both demand for and supply of funds. This analysis sheds light on why relationships exist in this market, despite the fact that the claims traded are secured with high-quality collateral.

5.3.1 The Effects of Relationships on Trading

We hypothesize that relationships may affect terms of trade among counterparts, such as the availability of credit and the price of the loan (Elyasiani and Goldberg, 2004; Ashcraft and Duffie, 2007; Afonso et al., 2014). Specifically, we analyze how relationships affect volumes and rates in the repo market, as well as the probability of a trade occurring. We adopt the following regression specification:

$$Y_{i,d,t} = f\left(\mathrm{IV}_{i,t}, \mathrm{DV}_{d,t}; \mathrm{RS}^{i}_{i,d,t}, \mathrm{RS}^{d}_{i,d,t}; \text{Fixed effects}\right) + \epsilon_{i,d,t}, \tag{7}$$

where $Y_{i,d,t}$ is a placeholder for three different dependent variables: the probability of trade (a dummy variable that takes the value of one when a trade occurs and zero otherwise), trade volume, and the associated repo rate. The definitions of the independent variables are the same as in (6).

We use a probit model to estimate the likelihood of a successful trade among all potential tradable pairs between investors and dealers. As discussed earlier, on any given t, we first form potential trade pairs between all dealers and subfund families in our sample. For each pair, the dependent variable equals one if a trade occurs, zero otherwise. We use OLS regressions for trade volume and repo rates, conditional on a trade occurring.

As shown in Table 4, the results support the view that relationships matter for TPR trades. Most coefficients are statistically significant at standard significance levels. As we can see in the first column, the stronger the relationship strength, the larger the probability of a trade occur. This result is consistent with our earlier finding of stable relationships over time. We also find that trade volumes increase with relationship strength for both investors and dealers, conditional on having a trade. Interestingly, for repo rates, we find that greater relationship strength leads to less bargaining power over the rate, as the MMFs with higher dependence on a given dealer may accept a marginally lower rate on their investment, while dealers with higher dependence on MMFs may need to pay higher funding costs.

The size effects are also worth noting. Consistent with our relationship formation results, the likelihood of successful trades is increasing in both investor and dealer sizes. Also, conditional on a trade occurring, trade volumes are increasing in size. In terms of repo rates, they do not depend on investor size but depend negatively on dealer size.

5.3.2 The Fed's ON RRP Exercises as Shocks to the Supply of Funds

How do relationships affect terms of trade when liquidity shocks occur? Evidence from the studies on the interbank loan market suggests that relationships can buffer such shocks (Ashcraft and Duffie, 2007; Afonso et al., 2014). Here, we first use the Fed's RRP as a quasi-natural experiment to study whether relationships may help buffer shocks to the supply of funds toward broker-dealers.

Under the ON RRP exercise, the Fed offers overnight reverse repo agreements (that is, the Fed borrows cash with the loan secured by collateral from the Fed's securities portfolio, in practice consisting of US Treasuries) to a broad set of counterparties, including nonbank institutions that are significant lenders in money markets (see Frost et al. (2015)). By borrowing from a set of TPR market participants, the Fed's ON RRP operations drain the funds that could otherwise be lent to broker-dealers. Thus, these operations effectively induce a negative shock to the supply of funds for dealers who typically borrow in the TPR market.

We estimate how the ON RRP operations affect the likelihood of trades as well as the terms of trade conditional on a trade having occurred. Our approach is to use a difference-in-differences (DID) method to analyze the effects of the ON RRP operations. To the best of our knowledge, this is the first study on the effect of ON RRP on the TPR market.[13]

We employ the following specification to estimate the ON RRP effects:

$$Y_{i,d,t} = f\left(\mathrm{RRP}; \mathrm{IV}_{i,t}, \mathrm{DV}_{d,t}; \mathrm{RS}^{i}_{i,d,t}, \mathrm{RS}^{d}_{i,d,t}; \text{Fixed effects}\right) + \epsilon_{i,d,t}, \tag{8}$$

where "RRP" contains the difference-in-difference policy variables. Namely, "RRP" includes the dummies "Eligible", a dummy taking the value of unity if the MMF sub-family is an eligible counterpart to ON RRP and zero otherwise), "After", a dummy taking the value of unity after the introduction of ON RRP and zero before that; and the DID term, the interaction between the two dummy variables. The coefficient of the DID term tells us the effect of the policy on the treatment group—the MMFs that are counterparties of the ON RRP operations. To see why, note that the first difference compares the outcomes in the private repo market before and after the ON RRP exercise began. However, in the period following the ON RRP introduction, there may be factors other than the ON RRP exercise that have affected the markets, such as regulatory changes or other variables that

[13] The ON RRP exercise started on September 23, 2013, to assess its effectiveness to set a soft floor on short-term interest rates, as part of the monetary policy normalization tools. The key policy parameters are the RRP offer rate, which is the highest overnight rate that the Fed is willing to pay on funds borrowed from RRP eligible counterparties, and the RRP cap, which is the maximum amount of volume that each counterparty can lend. The key parameters of the RRP exercises, the individual cap and the RRP offer rate, have changed over time over our sample period, as the exercise went through various phases of testing. These changes were unrelated to changes in the stance of monetary policy, reinforcing the notion that RRP testing was an exogenous shock to the TPR market.

are unobservable to the researcher. To control for these unobservables, the second difference compares the changes of trade terms related to counterparties, which are directly affected by ON RRP, to those of non-counterparties, which are not directly affected by ON RRP. This second difference would identify the net effect of the ON RRP operations on counterparties.

The results are presented in Table 5. As shown in the table, following the introduction of the RRP facility, the eligible counterparties to the Fed were less likely to enter a private repo trade; in the case that they did, they would transact at lower volumes and a marginally higher rate. These results are statistically significant. They imply that, first, the ON RRP appeared to have led to an overall decline in private repo volumes over time, over and above any market observed trends, and that second, this decline came from both changing the relationship structures between MMFs and dealers as well as the volumes. In other words, in aggregate, our results suggest that following the introduction of the ON RRP facility, MMFs replaced repos with dealers with repos with the Fed and those MMFs who remained in the private repo market had lower volumes in the repos they conducted. However, this shift likely offered a competitive edge for MMFs in negotiating rates in the private repo market, as the counterparty MMFs managed to get marginally higher repo rates.

We have established that the ON RRP significantly changed terms of trade in the TPR market. We now turn our focus to relationships and analyze how counterparties with stronger relations reacted to the ON RRP effect. In other words, is the effect of ON RRP on the private repo market asymmetric depending on the relationship patterns of MMFs with dealers? In order to answer this question, we interact the MMF relationship strength with the policy parameters.

The specification again builds upon the model of Equation (8) by including interactive terms between MMF relationship strength and RRP variables (that is, Eligible" and After). The coefficients of this triple interaction term $\text{Eligible} \times \text{After} \times \text{RS}^{i}_{i,d,t}$ measure how the effect of ON RRP on repo trading may depend on the relationship strength of the funds with their borrowing dealers.

The results are shown in Table 6. As we can see, following the ON RRP, eligible MMFs with higher dependence on dealers were less likely to shift toward the Fed and still maintained trades with higher overall volume (the addition of the two relevant interaction terms for the volume equation is positive) at marginally higher rates. These results suggest that MMFs with high dependency on dealers tend to maintain their relationships and are remunerated for this by getting higher rates. Therefore, relationships can help buffer liquidity (supply) shocks for dealers coming from the introduction of the ON RRP.

5.3.3 Treasury Auctions as Shocks to the Demand for Funds

We now use Treasury auctions as a laboratory to investigate the effect of stronger relationships in buffering shocks to dealers' demand for TPR funding—shocks that are caused by exogenous variations in Treasury auction amounts. The premise of our analysis is that the TPR market is a major funding source for securities dealers, who often use it to finance their purchases of Treasury collateral. We postulate that stronger relationships may facilitate funding for dealers, especially on days of exogenous shocks in the supply of Treasury collateral.

To test this hypothesis, we begin by estimating a proxy for the liquidity shocks in Treasury auctions inspired by an approach used by Afonso et al. (2014).[14] The idea is to remove movements correlated with observable features of the data, given the different types of collateral and maturities involved in these auctions. To do that, we regress the total allocated volume in each Treasury auction on fixed effects for the maturity, the type of securities, and lagged volumes (to take into account of the refinancing of past debt). We add up the residuals (by security type and maturity) per day and thus construct a daily Treasury auction liquidity shock series.

[14] We also ran these estimations using the actual allocated volumes in the Treasury auctions instead of the residuals, and the results are qualitatively the same. Lou et al. (2013) show that Treasury auctions have price impacts even though the time and amount of each auction are announced in advance. This effect is linked to dealers' limited risk-bearing capacity and end-investors' imperfect capital mobility. Their study implies that even if well-anticipated auctions can still generate exogenous shocks to dealers' demand for funding.

We then adopt the already familiar methodology to assess the impact of relationships on mitigating liquidity demand shocks. The model specification relies on the following equation:

$$Y_{i,d,t} = f\left(\text{Tr. auction}; \text{IV}_{i,t}, \text{DV}_{d,t}; \text{RS}^{i}_{i,d,t}, \text{RS}^{d}_{i,d,t}; \text{Fixed effects}\right) + \epsilon_{i,d,t}, \tag{9}$$

where $Y_{i,d,t}$ is a repo trade outcome variable and "Tr. Auction" includes the Treasury action shock series, as derived above, as well as the interaction between this series and the dealers' relationship strength with their lenders. The coefficients of the interaction terms, the DID effect, tell us how the impact of a positive shock to the dealer's demand for liquidity may depend on the strength of the dealer's relationship with its lenders. Other independent variables are the same as in (7). Note that the time fixed-effects included here also help control for seasonality in Treasury auctions.

The results are presented in Table 7. As we can see, stronger relationships lead to better funding ability of dealers for a given positive liquidity shock. Positive liquidity shocks lead to larger TPR volumes and rates. These results may be due to two reasons. First, dealers have to compete for funds more aggressively when the Treasury borrows a lot, driving up repo rates and volumes. Second, dealers need to finance their auction awards, which also puts upward pressure on rates and volumes. However, the probability of finding a match declines, although this result is not statistically significant.

How does having stronger relationships affect these results? On days of positive shocks in Treasury issuance, dealers who have stronger relationships with investors are more likely to trade with them, and, in general, dealers can achieve larger volumes (positive coefficient on Tr. auction $\times$ RS Dealer in the Volume equation) and lower rates (the coefficient of Tr. auction $\times$ RS Dealer on Rate equation is negative), compared with dealers who have weaker relationships with their trade partners. Therefore, relationships can also help to buffer liquidity (demand) shocks for dealers on Treasury auction days.

6 Conclusion

Recent financial market history has underlined the importance of understanding the trading mechanism in the OTC markets. While these markets trade a vast amount of securities in the modern economy, they tend to be opaque and are characterized by search frictions. This paper contributes to the nascent literature that provides quantitative evidence on the behavior of OTC market participants in mitigating these frictions. In particular, we provide the first analysis on the role of trading relationships in the TPR market, a large and important OTC funding market for trading secured claims. Our study complements the recent papers on the value of trading relationships in interbank markets in which banks trade unsecured excess reserves as well as in the dealer-intermediated fixed income markets.

We find that participants in the TPR markets maintain trading relationships with a relatively broad number of counterparties. However, large traders tend to interact with more counterparties than small traders, and small traders tend to form more concentrated relationships. This pattern is similar to the results found in both the interbank loan markets and the dealer-intermediated OTC markets. Moreover, we find that relationships tend to be stable, in that relationship formation depends strongly on past relationship strength and that for each trader, trade volumes over the entire extended sample period are distributed among a fairly small set of counterparts. Also interesting, our results suggest that there exists economies of scope in forming trading relationships, particularly from the investors' perspective. Specifically, we find that MMFs tend to form stronger relationships among dealers with whom the funds interact more outside the TPR market.

Trading relationships are valuable. In particular, we find that trading relationships help traders absorb liquidity shocks. We analyze two shocks specific to the TPR market. One is the Fed's ON RRP operations, which can be seen as a negative shock to the supply of funds to the dealers. We provide evidence that the ON RRP changed the structure of the market by creating conditions in which it was optimal for MMFs and dealers to sever relationships and therefore reduce the possibility of private repo trades. On the private trades that occur, the volume would be lower and the rate a bit higher, suggesting that the ON RRP increased the bargaining power of MMFs. However, stronger relationships can help mitigate negative shocks on the likelihood and volumes of trades, whereas they enhance further the bargaining power of MMFs. Two, we also analyze the impact of shocks resulting from exogenous variations in Treasury auctions. Positive surprises in Treasury auctions lead to an increase in the demand for funding by the dealers. Again we find a positive impact of trading relationships on the ability of dealers to obtain extra funding. That is, dealers who have stronger relationships with investors are more likely to trade on Treasury auction days and, in general, can achieve larger volumes and lower rates compared with dealers with weaker trading relationships with investors.

Overall, our results suggest that trading relationships play an important role in the TPR market. Despite the fact that market participants are generally large, sophisticated financial institutions and despite that the traded claims are secured by high-quality collateral, search frictions appear to be an important consideration in understanding the trading mechanism in this market. As such, the implication for future research is twofold. First, from the public policy point of view, it is important to understand the potential unintended consequences of the participation of the central banks in this market on the private market infrastructure–a point that echoes the cautious note by Frost et al. (2015). Second, further analysis should focus on the channel through which trade relationships reduce search frictions. In theory, repeated interactions may mitigate both information asymmetry and transaction costs. Additional data on how search and negotiation are carried out in this market would help us further analyze this issue.

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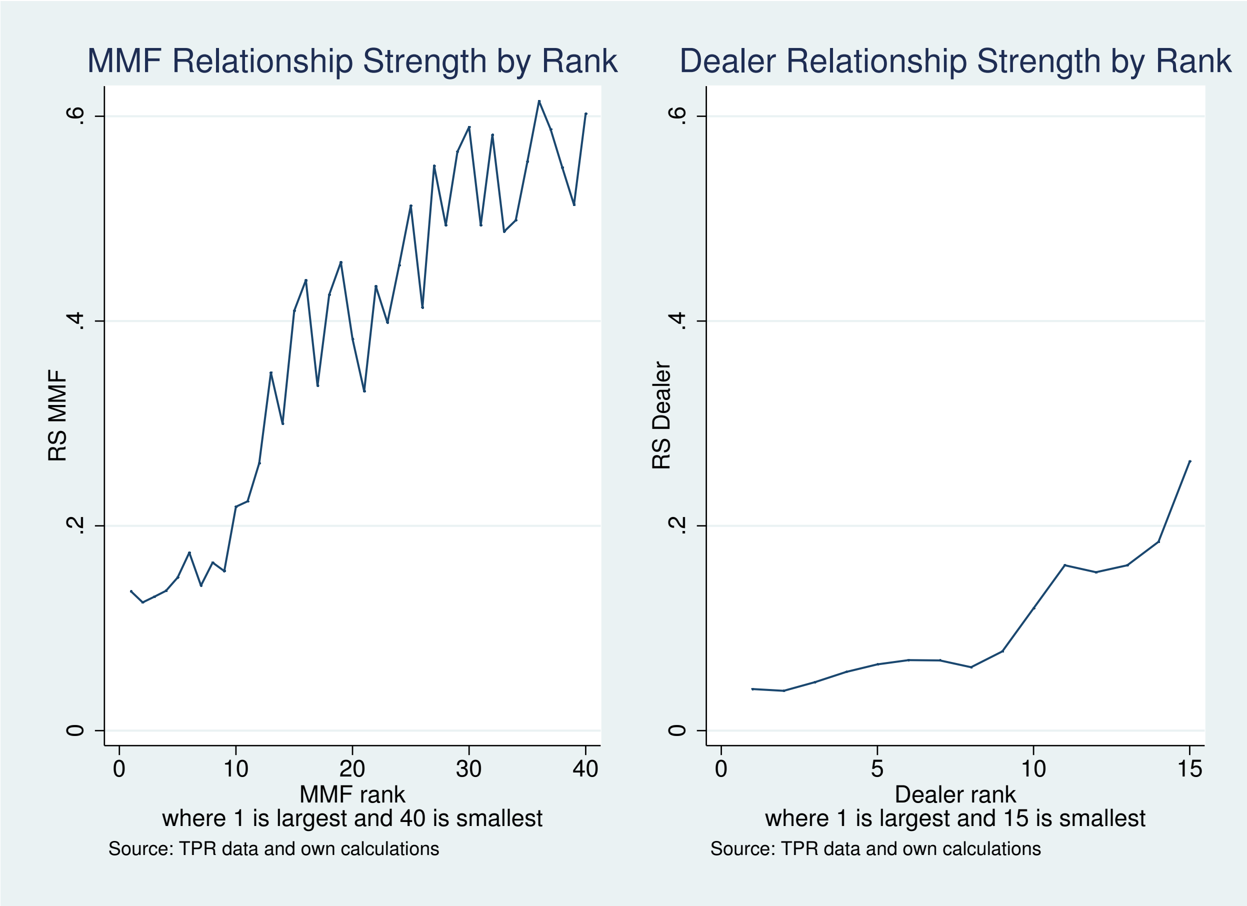
Figure 1: **Average Relationship Strength by Investor and Dealer Sizes**

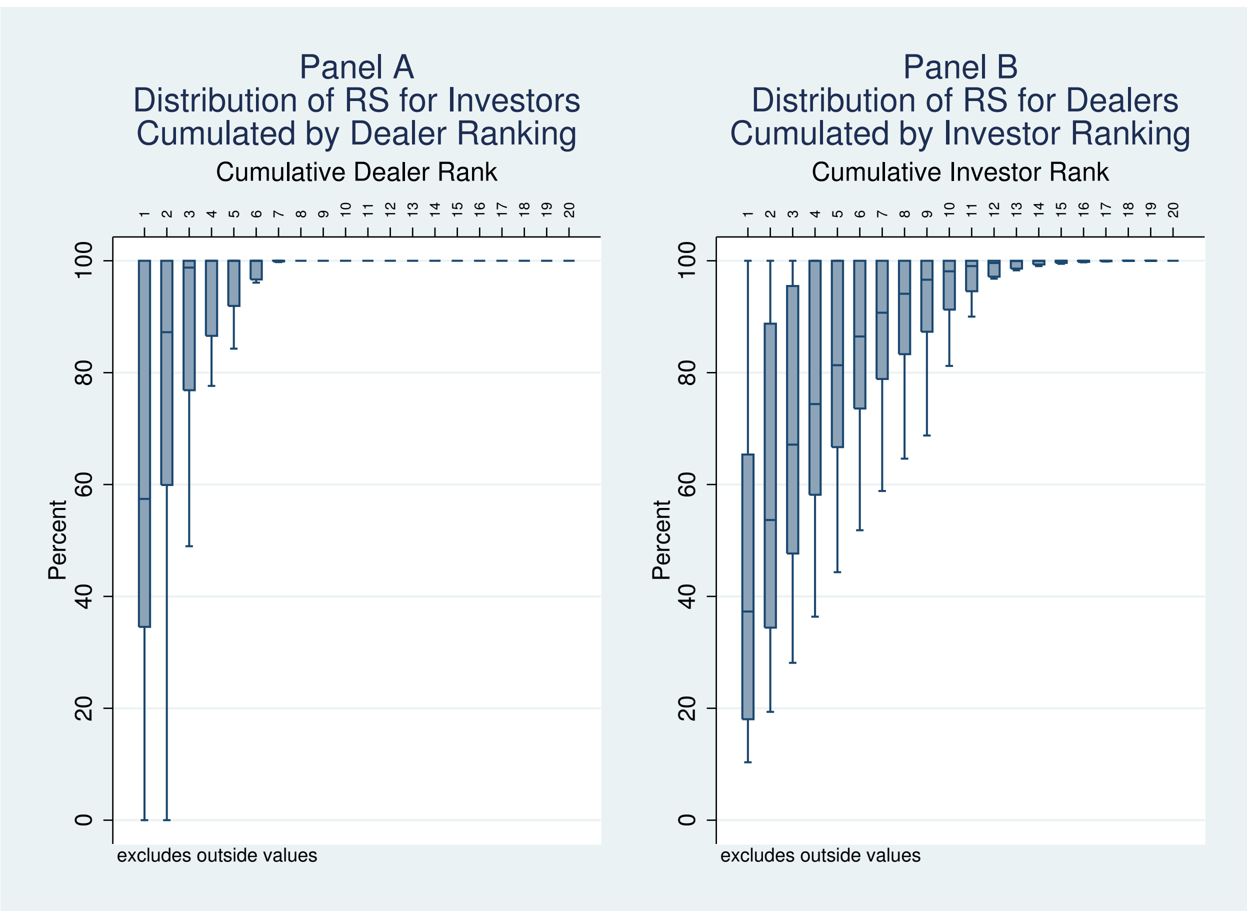
This figure plots the average relationship strength (RS) measures for the top 40 investors and the top 15 dealers. RS is averaged for each investor or dealer rank over time. A rank of one indicates the largest sized dealer or investor. As the rank increases, the size of investors and dealers declines. Investors are grouped by fund family and dealers by their ultimate parent.



Source: Federal Reserve and authors' calculations.

Figure 2: **Distribution of Long-Term Relationship Strength**

The figures plot the distribution of long-term relationship strength (LTRS) for investors (Panel A) and dealers (Panel B). LTRS is calculated using the same formula as (3) except that both denominator and numerator are aggregated over the entire sample. That is, LTRS represents volumes that each investor lends to a dealer (Panel A) or each dealer borrows from (Panel B) from an investor over the whole sample, as a percent of total volume lent or borrowed, respectively. We then accumulate LTRS over the rank of the counterparties, from the dealer (investor) with whom an investor (dealer) has the greatest LTRS to the smallest. The boxplots present the cumulative distribution of LTRS for investors (Panel A) and dealers (Panel B), by such cumulative ranking. The highlighted part of the boxplots presents the range of LTRS between the 25th and 75th percentiles, where the median is denoted with an inner line. The lower and upper lines in the boxplots represent approximately the 5th and 95th percentile, respectively. Values outside these extreme lines are omitted from the chart. Investors are grouped by fund family and dealers by their ultimate parent.



Source: The Federal Reserve and authors' calculations.

Table 1: **Summary Statistics of Triparty Repo Trades**

This table shows summary statistics of triparty repo transaction volumes and rates as well as proxies for the fund and dealer sizes. These statistics are estimated using transaction information aggregated over a day at the sub-fund-family and dealer parent levels. "Trade volume" is the daily transaction amount in billions of dollars. "IV" and "DV" are proxies for the sizes of sub-fund-families and dealers, respectively, measured by their respective transaction volumes, in billions of dollars, over the previous rolling month. See equations (1) and (2) for the formulas. We also show the statistics of the funds (again, at the sub-fund-family level) and the dealers by their respective fund-family ranking and dealer ranking. Ranking is computed monthly and labeled in the descending order, so that "Rank 1" refers to the fund family or the dealer with the largest transaction volume over the previous rolling month.

Variable	Mean	Median	St. Dev
	(1)	(2)	(3)
Trade Volume	0.44	0.23	0.63
IV	15.50	8.98	17.65
Rank 1	44.41	44.80	23.33
Rank 40	0.25	0.22	0.16
DV	27.19	23.46	16.95
Rank 1	53.34	58.32	11.90
Rank 15	2.54	1.93	2.18
TPR rate	6.88	5.21	4.99
N	23389		

SOURCE: The Federal Reserve System and authors' calculations.

Table 2: **Descriptive Statistics of Trading Relationship**

This table presents descriptive statistics of the relationship variables. "RS MMF" and "RS Dealer" are, respectively, the relationship strength of a fund and a dealer with respect to counterparties. "RF MMF" and "RF Dealer" are relationship formation variables. The "BRS MMF–CP/CDs" and "BRS MMF–Other repos" variables are broad relationship strength (BRS) measures for MMFs in the CP/CDs trades and repos other than overnight Treasury TPR trades, respectively, while "BRS Dealer–CP/CDs" and "BRS Dealer–Other repos" are the respective measures for dealers. See definition details in Section 4.3. The first column, denoted by Var. = 0, presents the percent of observations where each respective variable equals zero in the sample containing all possible interactions between MMFs and dealers. The columns under Var. > 0 show statistics conditional on each respective variable being greater than zero. Note that investors are aggregated at the sub-fund-family level and dealers at the dealer parent level. Ranking is computed monthly at the fund-family and the dealer parent levels, and labeled in the descending order, so that "Rank 1" refers to the fund family or the dealer with the largest transaction volume over the month.

Variable	Var.=0	Var.>0		
	Percent	Mean	Median	St. Dev
	(1)	(2)	(3)	(4)
RS MMF	74.36	0.22	0.13	0.25
Rank 1	50.85	0.09	0.07	0.09
Rank 40	89.11	0.63	0.57	0.34
RS Dealer	76.79	0.07	0.04	0.12
Rank 1	45.08	0.03	0.02	0.04
Rank 15	93.93	0.28	0.20	0.24
RF MMF	76.13	0.24	0.14	0.26
Rank 1	53.8	0.10	0.07	0.10
Rank 40	89.11	0.64	0.59	0.33
RF Dealer	79.5	0.08	0.04	0.13
Rank 1	49.00	0.03	0.02	0.05
Rank 15	94.5	0.31	0.24	0.26
BRS MMF - CP and CDs	57.78	0.16	0.12	0.15
Rank 1	37.76	0.11	0.10	0.08
Rank 15	62.68	0.18	0.15	0.16
BRS Dealer - CP and CDs	65.19	0.05	0.01	0.09
Rank 1	75.16	0.07	0.02	0.09
Rank 15	66.91	0.05	0.01	0.11
BRS MMF - Other repo	63.57	0.18	0.12	0.20
Rank 1	35.93	0.11	0.08	0.11
Rank 15	82.10	0.36	0.29	0.24
BRS Dealer - Other repo	69.58	0.06	0.02	0.08
Rank 1	48.2	0.03	0.01	0.05
Rank 15	75.34	0.07	0.03	0.10

SOURCE: Federal Reserve and authors' calculations.

Table 3: **Determinants of Relationship Formation**

This table presents the results from probit and OLS regressions estimating the determinants of relationship formation. The dependent variables, "RF MMF" and "RF Dealer," are relationship formation variables as defined in equation (4). The independent variables are defined as follows: "IV" and "DV" are proxies for the sizes of investors and dealers, measured by their respective transaction volumes, in millions of dollars, over the previous month. See equations (1) and (2). "RS MMF" and "RS Dealer" are, respectively, the relationship strength of a fund and a dealer with respect to counterparties. The "BRS MMF–CP/CDs" and "BRS MMF–Other repos" are BRS measures for MMFs in the CP/CDs trades and repos other than overnight Treasury TPR trades, respectively, while "BRS Dealer–CP/CDs" and "BRS Dealer–Other repos" are the respective measures for dealers. Columns (1) and (2) present the coefficients from a probit model of the factors affecting the probability that the dependent variable is positive. That is, the probit dependent variable equals 1 when RF is positive and zero otherwise. Columns (3) and (4) present the OLS coefficients of the factors affecting the dependent variable, conditional on that the latter is positive. Investors are aggregated at the sub-fund-family level and dealers at the dealer parent level. All regressions include fixed effects to control for unobservable heterogeneity at the fund family, dealer parent, and macroeconomic levels. Heteroskedasticity-robust p-values are shown in parentheses. *, **, and *** denote the 10, 5, and 1 percent significance levels, respectively.

	Pr(RF > 0)		OLS	
Indp. Var.	RF MMF	RF Dealer	RF MMF	RF Dealer
	(1)	(2)	(3)	(4)
IV	0.231	13.697***	-0.730***	0.027
	(0.803)	(0.000)	(0.000)	(0.494)
DV	4.254***	8.420***	0.063	-0.243**
	(0.005)	(0.000)	(0.687)	(0.012)
RS MMF	6.185***	4.471***	0.782***	-0.010***
	(0.000)	(0.000)	(0.000)	(0.002)
RS Dealer	10.450***	14.773***	0.009	0.883***
	(0.000)	(0.000)	(0.415)	(0.000)
BRS MMF - CP and CD	0.471***	0.731***	0.019***	0.000
	(0.000)	(0.000)	(0.005)	(0.934)
BRS Dealer - CP and CD	-1.068***	-1.516***	-0.022	-0.013
	(0.000)	(0.000)	(0.290)	(0.241)
BRS MMF - Other Repo	1.085***	2.129***	0.023**	0.004
	(0.000)	(0.000)	(0.020)	(0.186)
BRS Dealer - Other Repo	0.132	-0.741***	0.056***	0.045***
	(0.540)	(0.005)	(0.001)	(0.000)
N	44,662	44,662	12,185	12,185

SOURCE: Federal Reserve and authors' calculations.

Table 4: **The Effects of Relationships on Triparty Repo Trading**

This table presents the results of regressions estimating the effects of relationship strength on the probability of a trade over all potential trading pairs between funds and dealers and, conditional on having a trade, on trade volumes and repo rates. The independent variables are defined as follows: "IV" and "DV" are proxies for the sizes of investors and dealers, measured by their respective transaction volumes, in millions of dollars, over the previous month. See equations (1) and (2). "RS MMF" and "RS Dealer" are, respectively, the relationship strength of a fund and a dealer with respect to counterparties. Investors are aggregated at the sub-fund-family level and dealers at the dealer parent level. All regressions include fixed effects to control for unobservable heterogeneity at the fund family, dealer parent, and macroeconomic levels. Heteroskedasticity-robust p-values are shown in parentheses. *, **, and *** denotes the 10, 5, and 1 percent significance levels, respectively. Rate and spreads are in percentage points.

Indp. Var.	Pr(trade)	Volume	Rate
	(1)	(2)	(3)
RS MMF	5.330***	0.577***	-0.279***
	(0.000)	(0.000)	(0.000)
RS Dealer	13.484***	2.837***	0.114**
	(0.000)	(0.000)	(0.035)
IV	0.015***	0.007***	-0.001
	(0.000)	(0.000)	(0.622)
DV	0.005***	0.008***	-0.003**
	(0.000)	(0.000)	(0.012)
$\overline{R}^2$		0.595	0.978
N	88,375	20,397	20,397

Source: Federal Reserve and authors' calculations.

Table 5: **Impact of the Fed's ON RRP on the TPR Trading**

This table presents results of difference-in-difference regressions estimating the effects of the Fed's ON RRP—shocks to the supply of funds to dealers—on the TPR trading, including the probability of a trade over all potential trading pairs between funds and dealers and, conditional on having a trade, on trade volumes and repo rates. "After" is a dummy that takes the value of 1 for dates after the start of the RRP exercise. "Eligible" is a dummy that takes the value of 1 for eligible MMFs. Other independent variables are defined as follows: "IV" and "DV" are proxies for the sizes of investors and dealers, measured by their respective transaction volumes, in millions of dollars, over the previous month. See equations (1) and (2). "RS MMF" and "RS Dealer" are, respectively, the relationship strength of a fund and a dealer with respect to counterparties calculated using transactions over the previous month. Investors are aggregated at the sub-fund-family level and dealers at the dealer parent level. All regressions include fixed effects to control for unobservable heterogeneity at the fund family, dealer parent, and macroeconomic levels. Heteroskedasticity-robust *p*-values are shown in parentheses. *, **, and *** denote the 10, 5, and 1 percent significance levels, respectively. Rate and spreads are measured in percentage points.

Indp. Var.	Pr(trade) (1)	Volume (2)	Rate (3)
IV	0.020***	0.007***	-0.000
	(0.000)	(0.000)	(0.228)
DV	0.005***	0.009***	-0.002**
	(0.000)	(0.000)	(0.011)
RS MMF	5.272***	0.550***	-0.292***
	(0.000)	(0.000)	(0.000)
RS Dealer	13.317***	2.804***	0.208***
	(0.000)	(0.000)	(0.004)
Eligible	0.013	0.517***	0.118
	(0.634)	(0.000)	(0.207)
After	-0.048	-0.174***	-12.652***
	(0.672)	(0.010)	(0.000)
Eligible × After	-0.335***	-0.069***	0.107***
	(0.000)	(0.000)	(0.000)
$\overline{R}^2$		0.603	0.979
N	88,375	20,397	20,397

SOURCE: Federal Reserve and authors' calculations.

Table 6: **Do Relationships Buffer the Impact of ON RRP on TPR Trading?**

This table presents results of regressions estimating how relationships may buffer the effects of the Fed's ON RRP—shocks to the supply of funds to dealers—on TPR trading, including the probability of a trade over all potential trading pairs between funds and dealers and, conditional on having a trade, on trade volumes and repo rates. The approach is to interact relationship strength variables with the difference-in-difference terms in the previous table. "After" is a dummy that takes the value of 1 for dates after the start of the RRP exercise. "Eligible" is a dummy that takes the value of 1 for for eligible MMFs. Other independent variables are defined as follows: "IV" and "DV" are proxies for the sizes of investors and dealers, measured by their respective transaction volumes, in millions of dollars, over the previous month. See equations (1) and (2). "RS MMF" and "RS Dealer" are, respectively, the relationship strength of a fund and a dealer with respect to counterparties calculated using transactions over the previous month. See equation (3). Investors are aggregated at the sub-fund-family level and dealers at the dealer parent level. All regressions include fixed effects to control for unobservable heterogeneity at the fund family, dealer parent, and macroeconomic levels. Heteroskedasticity-robust p-values are shown in parentheses. *, **, and *** denote the 10, 5, and 1 percent significance levels, respectively. Rate and spreads are measured in percentage points.

Indp. Var.	Pr(trade)	Volume	Rate
	(1)	(2)	(3)
IV	0.017***	0.008***	-0.001
	(0.000)	(0.000)	(0.116)
DV	0.007***	0.007***	0.000
	(0.000)	(0.000)	(0.978)
RS MMF	7.425***	0.642***	-0.218***
	(0.000)	(0.000)	(0.000)
RS Dealer	12.555***	2.930***	0.111
	(0.000)	(0.000)	(0.137)
Eligible	0.172***	-0.001	-0.039
	(0.000)	(0.891)	(0.703)
After	-0.105	-0.277***	-15.947***
	(0.416)	(0.000)	(0.000)
Eligible × After	-0.375***	-0.107***	0.099***
	(0.000)	(0.000)	(0.000)
Eligible × RS MMF	-3.987***	-0.319***	0.154
	(0.000)	(0.000)	(0.113)
After × RS MMF	-3.785***	-0.174***	-0.123***
	(0.000)	(0.000)	(0.001)
Eligible × After × RS MMF	3.617***	0.388***	0.431***
	(0.000)	(0.000)	(0.002)
$\overline{R}^2$		0.605	0.979
N	101,452	20,380	20,380

SOURCE: Federal Reserve and authors' calculations.

Table 7: **Do Relationships Buffer the Impact of Treasury Auctions on TPR Trading?**

This table presents results of regressions estimating how relationships may buffer the effects of Treasury auctions—shocks to the demand for funds by dealers—on the TPR trading, including the probability of a trade over all potential trading pairs between funds and dealers and, conditional on having a trade, on trade volumes and repo rates. "Tr. auction" is the residual (in billions of dollars) from regressing the total amount of Treasuries (excluding TIPS) allocated in the auctions on securities characteristics, maturities, and lagged auction allocation volumes. Our difference-in-difference approach is to interact relationship strength variable with "Tr. auction." Other independent variables are defined as follows: "IV" and "DV" are proxies for the sizes of investors and dealers, measured by their respective transaction volumes, in millions of dollars, over the previous month. See equations (1) and (2). "RS MMF" and "RS Dealer" are, respectively, the relationship strength of a fund and a dealer with respect to counterparties calculated using transactions over the previous month. See equation (3). Investors are aggregated at the sub-fund-family level and dealers at the dealer parent level. All regressions include fixed effects to control for unobservable heterogeneity at the fund family, dealer parent, and macroeconomic levels. Heteroskedasticity-robust *p*-values are shown in parentheses. *, **, and *** denote the 10, 5, and 1 percent significance levels, respectively. Rate and spreads are measured in percentage points.

Indp. Var.	Pr(trade)	Volume	Rate
	(1)	(2)	(3)
IV	0.011***	0.008***	0.001***
	(0.000)	(0.000)	(0.000)
DV	0.001**	0.016***	-0.007
	(0.034)	(0.000)	(0.283)
RS MMF	6.779***	0.593***	–0.282***
	(0.000)	(0.000)	(0.000)
RS Dealer	27.543***	9.718***	-0.143*
	(0.000)	(0.000)	(0.051)
Tr. auction	-0.028	0.047***	2.715***
	(0.187)	(0.003)	(0.000)
Tr. auction × RS Dealer	0.710**	0.037	–0.189***
	(0.015)	(0.095)	(0.001)
$\overline{R}^2$		0.715	0.977
N	84,965	23,538	23,538

SOURCE: Federal Reserve and authors' calculations.