

Federal Reserve Bank of New York
Staff Reports

The Tri-Party Repo Market before the 2010 Reforms

Adam Copeland
Antoine Martin
Michael Walker

Staff Report no. 477
November 2010

This paper presents preliminary findings and is being distributed to economists and other interested readers solely to stimulate discussion and elicit comments. The views expressed in this paper are those of the authors and are not necessarily reflective of views at the Federal Reserve Bank of New York or the Federal Reserve System. Any errors or omissions are the responsibility of the authors.

The Tri-Party Repo Market before the 2010 Reforms

Adam Copeland, Antoine Martin, and Michael Walker

Federal Reserve Bank of New York Staff Reports, no. 477

November 2010

JEL classification: E44, E58, G24

Abstract

This paper provides a descriptive and quantitative account of the tri-party repo market before the reforms proposed in 2010 by the Task Force on Tri-Party Repo Infrastructure (Task Force 2010). We provide an extensive description of the mechanics of this market. We also use data from July 2008 to early 2010 to document quantitative features of the market. We find that both the level of haircuts and the amount of funding were surprisingly stable in this market. The stability of the margins is in contrast to evidence from other repo markets. Perhaps surprisingly, the data reveal relatively few signs of stress in the market for dealers other than Lehman Brothers, on which we provide some evidence. This suggests that runs in the tri-party repo market may occur precipitously, like traditional bank runs, rather than manifest themselves as large increases in margins.

Key words: tri-party repo, wholesale funding, short-term funding

Copeland, Martin, Walker: Federal Reserve Bank of New York (e-mail: adam.copeland@ny.frb.org, antoine.martin@ny.frb.org, michael.walker@ny.frb.org). The authors thank Viral Acharya, Brian Begalle, Michele Braun, Lucinda Brickler, Dan Dehlinger, Darrell Duffie, Michael Fleming, Ken Garbade, Gary Gorton, Jamie McAndrews, Susan McLaughlin, Steve Pesek, Andy Sturm, and members of the Task Force for helpful comments on an earlier draft. The views expressed in this paper are those of the authors and do not necessarily reflect the position of the Federal Reserve Bank of New York or the Federal Reserve System.

1 Introduction

This paper aims to shed some light on the US tri-party repo market, an important funding market that played a role in some of the key events associated with the recent financial crisis. The Task Force on Tri-Party Repo Infrastructure (Task Force 2010) notes that “At several points during the financial crisis of 2007-2009, the tri-party repo market took on particular importance in relation to the failures and near-failures of Countrywide Securities, Bear Stearns, and Lehman Brothers. The potential for the tri-party repo market to cease functioning, with impacts to securities firms, money market mutual funds, major banks involved in payment and settlements globally, and even to the liquidity of the U.S. Treasury and Agency securities, has been cited by policy makers as a key concern behind aggressive interventions to contain the financial crisis.”

We provide a descriptive and quantitative account of the tri-party repo market before the reforms proposed in 2010 by the Task Force.¹ In particular, we describe in some detail the mechanics of this market and some of its vulnerabilities. We also use data collected by the Federal Reserve Bank of New York (FRBNY) to document quantitative features of this market. Our data covers the period from July 2008 to the beginning of 2010.

The tri-party repo market is a large funding market in which dealers fund their portfolios of securities through repurchase agreements (repos). The largest cash providers in this market are money market mutual funds and securities lenders that seek a short-term investment for their available cash. Two tri-party clearing banks, JPMorgan Chase and the Bank of New York Mellon, provide intermediation services to the dealers and the cash investors. The vulnerabilities of the tri-party repo market are magnified by its size, the fact that the share of less liquid collateral was growing before the crisis, and the fact that the majority of funding was short-term, usually overnight. The size of the market reached \$2.8 trillion and the size of the largest portfolios financed by dealers exceeded \$400 billion at the peak of the market. The share of

¹While this paper focuses on the US tri-party repo market, some information on repo markets in other countries can be found in CPSS (2010).

less liquid collateral approached 30 percent of the collateral funded in the market at the peak and has decreased to less than 20 percent in 2010.

We find that both the level of haircuts and the amount of funding were surprisingly stable in this market during the period for which we have data, from July 2008 to early 2010. The stability of the margins is in contrast to evidence from other repo markets. Of course, this apparent stability did not prevent the tri-party repo market from contributing to the problems experienced by Lehman Brothers, on which we provide some evidence. The available evidence suggests that runs in the tri-party repo market may occur precipitously, more like traditional bank runs, rather than manifest themselves in the form of large increases in margins.

Haircuts in the tri-party repo market barely moved during the crisis. This is in stark contrast with the study of Gorton and Metrick (2009) of an interdealer market for less liquid collateral and the experience of some other repo markets. The stability of haircuts in tri-party repo seems to be due, in part, to the behavior of some large cash investors who look at the counterparty to a repo first and to the collateral second. For these investors, withdrawing funding from a troubled counterparty altogether seems preferable to increasing margins. The stability of haircuts suggest that while the “margin spirals” described in Geanakoplos (2003) or Brunnermeier and Pedersen (2009) seem to characterize the experience of some repo markets, the tri-party repo market is very different.

The data shows quite stable relationships between cash investors and the dealers they perceive to be creditworthy. While the amount of funds provided by some large cash investors does fluctuate somewhat, dealers can generally count on the same set of counterparties providing a minimum amount of funding. In particular, we find few examples of interruptions in the relationship between a cash investor and a dealer. The total amount of collateral funded in the tri-party repo market decreased between July 2008 and early 2010, but anecdotal evidence suggests this could be due, in large part, to dealers’s desire to reduce their leverage. While the market may have been stressed, it appears that most dealers were able to maintain stable funding in the tri-party repo market from July 2008 to early 2010. It is a challenge to reconcile

the apparent stability of the tri-party repo market with the dramatic events related to the failure of Lehman Brothers, to which the tri-party repo market seems to have contributed, as we document in section 5.1.

Another puzzle is the difference in the behavior of haircuts between the tri-party repo market and other repo markets. While we lack the data to provide a definitive answer, several features of the market appear to be relevant: 1) Cash investors and dealers appear to establish long-term relationships. If investors attach value to their relationships with dealers, they may be willing to continue to provide tri-party repo lending to a dealer without raising margins, even in stressed circumstances. 2) Some cash investors appear to be reluctant or unprepared to take possession of the collateral and prefer to withdraw funding if they think a dealer is not credit worthy. The level of haircuts and the type of collateral may be unimportant for such investors and they may not manage either carefully. 3) Tri-party repos have very short terms, usually overnight. This allows investors to pull their funding at a moment's notice if a dealer becomes too weak. Additional data on different repo markets would help ascertain the importance of each of these features. Lack of data also prevents us from considering the differences between secured and unsecured funding. Anecdotal evidence suggests that unsecured funding behaves differently from both bilateral and tri-party repos. In particular, it appears that tri-party repo funding is typically more stable than unsecured funding, despite the unwillingness of some cash investors to take possession of the collateral.

The features described in the last paragraph also help explain why “runs” in the tri-party repo market are likely to happen precipitously, rather than through a gradual process. In that respect, tri-party repo runs resemble traditional bank runs. The fragility of the tri-party repo market is also exacerbated by some institutional features, such as the morning “unwind” of repos, as we describe in section 4. Hence, the apparent stability of the tri-party repo market during the crisis should not obscure the fact that runs, when they occur, can have devastating and systemic consequences, as was the case with the failure of Lehman. This risk underscores the need for reform in this market.

Another potentially important factor in the apparent stability of the tri-party repo market was the presence of the Primary Dealer Credit Facility (PDCF) during the period for which we have data (see Adrian, Burke, and McAndrews 2009). Many market participants have mentioned that the PDCF played an important role in the stability of the market.

The remainder of the paper is organized as follows: Section 2 describes the mechanics of the tri-party repo market in more detail and section 3 provides a quantitative assessment of the (relatively) stable period from July 2009 to early 2010. Section 4 discusses the fragility of the tri-party repo market and section 5 looks at the data during the height of the crisis, between July 2008 and July 2009. Section 6 concludes.

2 The tri-party repo market in the US

In the US, a tri-party repo is a form of repo for which a third party, called the clearing bank, provides intermediation services to the cash investor and the collateral provider.² Tri-party repos are popular in part because of the efficiency gains associated with the intermediation role of the clearing bank. Indeed, the efficiency of the tri-party repo market, and the fact that so many institutions use it, are among the reasons the Federal Reserve uses this instrument to implement monetary policy.

While this paper focuses specifically on the tri-party repo market, there are other repo markets. Dealers also use bilateral repos, known as DvP (delivery versus payment) repos, to obtain funding. However, because DvP repos are not as convenient as tri-party, they are believed to represent a small share of dealer funding. Repos are also used to redistribute cash between dealers. For example, broker dealers can exchange cash and general collateral with each other in the GCF repo[®] market (Fleming and Garbade 2003).³ There is also an interdealer

²Appendix C defines and provides a brief overview of repos.

³General collateral is collateral for which supply is abundant relative to demand. An investor accepting general collateral may care about the class of collateral she receives, but not about the specific issue. This is in contrast to “special” collateral, for which supply is short relative to demand. An investor seeking special collateral cares about the specific issue she receives.

market for less liquid collateral, which is studied in Gorton and Metrick (2009). Prime brokers also use repos to provide cash to hedge funds, or other clients, against securities using bilateral repos. In the remainder of this section, we describe the cash investors, the collateral providers, and the clearing banks in the US tri-party repo market, as well as the mechanics of this market.

2.1 Collateral providers

The collateral providers supplying the majority of collateral in the tri-party repo market are “primary dealers”. Primary dealers are banks or securities broker-dealers that can trade directly with the Federal Reserve.⁴ Some large hedge funds and other institutions with large portfolios of securities also participate in the tri-party repo market, but they represent a small share of the total volume. From July 2008 to January 2010, there were at least 40 collateral providers in the tri-party repo market.⁵ This side of the market is concentrated, with the top 5 collateral providers accounting for 57% of borrowing and the top 10 accounting for 88%. We use the terms “collateral providers” and “dealers” interchangeably in this paper.

Dealers hold securities for several reasons. Some securities constitute inventories as part of the dealer’s market-making business, others are part of the proprietary holdings of the dealer as a form of investment. Collateral providers also obtain securities through intermediation. For example, prime brokers receive collateral through their prime brokerage services. As part of that business, they provide cash to their clients, such as hedge funds, usually through a bilateral repo transaction in which the client is the collateral provider. In some cases, broker dealers can rehypothecate the collateral to a cash investor through tri-party repo. In this way, the broker dealer acts as an intermediary, transferring cash from an investor to a hedge fund and collateral from a hedge fund to an investor. The broker dealer earns profits on the difference between interest rates on the bilateral repo with the hedge fund and on the tri-party repo with the cash investor. In addition, if the haircut in tri-party is lower than the haircut the broker dealer obtains

⁴For more information on primary dealers, see <http://www.newyorkfed.org/markets/primarydealers.html>.

⁵Our data contains 26 dealers during the “stable” period, listed in appendix A, but does not include some dealers with very little activity in the tri-party repo market.

from its client, then the broker dealer is able to generate cash, which can be used to earn an additional return.

To economize on their use of capital, dealers prefer to borrow cash to purchase the securities they hold (Tuckman 2010). In turn, the securities can serve as collateral to obtain cash. This is one way in which securities dealers can obtain leverage. Consider the stylized example of a dealer with \$1 billion in capital. This dealer can use its capital to buy \$1 billion in securities and repo these securities to obtain cash. If the haircut on the repo is 5%, the dealer can get \$950 million in cash. With this cash, the dealer can buy new securities and repo them out to get more cash. Assuming the same haircut, the dealer can get an additional \$902.5 million in cash in that way. Continuing this process, the dealer can obtain a portfolio of securities worth \$20 billion with its \$1 billion in capital.⁶

As an alternative to obtaining financing in the tri-party repo market, dealers can engage in DvP repos. However, DvP repos are not as flexible as tri-party repos and some investors may find it too costly or cumbersome to engage in such repos. Dealers can also obtain unsecured funding by issuing commercial paper (CP) or medium term notes (MTN). In the past few years, dealers have progressively moved away from unsecured financing toward secured financing, notably tri-party repos. One reason was the belief at the time that secured financing was generally more stable and less affected by market sentiment (Friedman 2010). For that reason, the relative fragility of the tri-party repo market was a surprise to many market participants.

2.2 Cash investors

The set of cash investors in the tri-party repo market is more numerous and diverse than the set of collateral providers. There are over 4,000 individual firms active as cash investors. Money market mutual funds form one large group of investors, representing between a quarter and a third of the cash invested in that market. Another large group, representing about 25

⁶The formula to find the value of the portfolio of securities is: $1 + 0.95 + 0.95^2 + \dots = \sum_{i=0}^{\infty} 0.95^i = \frac{1}{1-0.95} = 20$. This example provides an upper bound, as it assumes that the dealer is fully levered, which is not generally the case.

percent, is securities lenders. Securities lenders use the tri-party repo market to re-invest the cash collateral they receive when they loan securities.⁷

The cash investor side of the tri-party repo market is less concentrated than the collateral-provider side but is concentrated nonetheless. The largest 10 investors account for about 60% of the lending. Unlike the collateral-provider side, however, there is a long tail of smaller investors composed of municipalities and individual businesses. Investors typically lend to a number of different collateral providers as a way to diversify their risk.

Cash investors seek to earn interest on their available cash. Some lenders are interested in investing for very short durations because they may need the cash on short notice. For example, money market mutual funds may need cash to accommodate redemption requests from their investors. Short-term repos can also be used as a risk management tool by cash investors. Indeed, if an investor becomes concerned about the health of a collateral provider, it can choose to redirect its funding on short notice to a healthier collateral provider.

Some cash investors can use DvP repos as an alternative to tri-party. However, DvP requires the investor to take possession of the collateral and perform other back-office functions that the clearing banks perform in tri-party.⁸ Cash investors can also invest in unsecured instruments such as CP or certificates of deposits (CD).

⁷In the US, a security cannot be sold short by an institution that does not borrow the security to make delivery, an activity also known as “naked” short selling (SEC regulation SHO, see <http://www.sec.gov/divisions/marketreg/mrfaqregsho1204.htm>). The ban on naked short selling creates an important role for securities lending, which allows an institution that wants to sell a securities short to borrow it. Custodial banks often provide the service of lending the securities of their clients. In the US, most securities lending is done against cash collateral. Hence, securities lenders usually have large pools of cash that they seek to re-invest, on behalf of their clients. While investment strategies for these pools of cash may differ, they often resemble the investment strategies of money market mutual funds. This is in part due to the fact that securities lenders must return the cash collateral to a borrower of a security as soon as the borrower returns the security. Since the return of the security is at the discretion of the borrower, the securities lender is exposed to “redemption requests” that are somewhat similar to pressures faced by money market mutual funds.

⁸In both tri-party and DvP repos, risk management is the responsibility of the investor.

2.3 Clearing banks

There are two tri-party repo clearing banks in the U.S. market: JPMorgan Chase (JPMC) and the Bank of New York Mellon (BNYM). The clearing banks play an important role as intermediaries between the collateral provider and the cash investor. They take custody of securities used as collateral in a tri-party repo transaction, they value the securities and make sure that the specified margin is applied, they settle the transaction on their books, and they offer services to help dealers optimize the use of their collateral. Note that the tri-party repo clearing banks do not match dealers with cash investors nor do they play the role of brokers in that market.

By taking custody of the collateral, the clearing banks provide a guarantee to the cash investor that the collateral is segregated and identifiable in case of default of the collateral provider. This reduces the legal risk faced by the cash investors.

The clearing bank assigns a value to the securities that are traded, which determines the number of securities that need to be pledged as collateral for a given dollar amount. To value securities, the clearing banks rely on price information provided to them by outside vendors. For securities that are actively traded, such as Treasuries, the price used for tri-party is typically that security's market price, evaluated at the close of the previous day's market. If a market price is not available, vendors can provide prices derived from models. Each clearing bank sets policies that determine what price applies in special circumstance, such as if vendor prices conflict or are absent, or the length of time before a modeled price is considered stale, for example.

The number of securities that needs to be pledged also depends on the applicable haircut. As we explain in more detail in section 2.4, haircuts are not negotiated at the trade level but are instead written into the appendix of the tri-party repo custodial agreement between the cash investor, the collateral provider, and the clearing bank. While it is possible to change the appendix containing the haircuts, the change may not apply until the next day. Such changes are only made occasionally.

The cash investors and the collateral providers hold balances and securities accounts on the books of a clearing bank.⁹ Typically, dealers hold an account with only one clearing bank, usually the custodian they have selected for their Fed-eligible securities.¹⁰ In contrast, cash investors typically hold accounts with both clearing banks. This allows the investors to diversify their exposures across many dealers, irrespective of the clearing bank an individual dealer relies upon to settle its tri-party repos. To settle the initial leg of a repo, the clearing bank moves securities from the collateral provider's securities account to the cash investor's securities account and moves cash in the opposite direction in the cash accounts, on its books. These flows are reversed to settle the return leg of the repo. Settling on the books of the clearing bank is particularly convenient for repos with multiple issues of collateral as, otherwise, the different pieces may have to be sent separately over the Fedwire[®] Securities Service, or DTC for non-Fed eligible securities.

As we explain in section 2.4, tri-party repos are arranged in the morning, before the collateral providers know exactly the composition of the portfolio they will need to finance. A trade specifies what collateral is acceptable but the exact collateral allocation is made at the end of the day, when the dealer's portfolio is known. The clearing banks make proprietary algorithms available to dealers to help them allocate collateral to specific repo trades in the least costly way, based on the applicable haircuts.

The clearing banks act as an agent to the collateral providers and the cash investors in all the roles noted above. In the U.S. tri-party repo market, the clearing banks also play the role of principal because they finance the collateral provider's securities during the day. This role creates operational efficiencies but is also a source of weakness in the market. As described in more detail in section 2.4, each morning the clearing banks "unwind" the prior day's repos, sending cash back to the investors and securities back to the collateral providers. This gives

⁹The term 'cash account' is also used to describe the balances account.

¹⁰Dealers cannot participate directly in Fedwire and use custodial banks as agents to settle sales or purchases of securities as well as to hold the securities in safekeeping. Fed-eligible securities are securities that can be settled on the Fedwire[®] Securities Service, while Non-Fed eligible, also called DTC-eligible, can be settled by the Depository Trust Company (DTC).

collateral providers access to their securities during the business day, which they need to conduct their market-making activities or to meet their settlement obligations, while creating an exposure to the clearing bank secured by the portfolio of securities.

2.4 Timing of events

In this section, we describe the timing of events related to a tri-party repo. This description focuses on market practice prior to the proposed reforms announced on May 17, 2010 and highlights the weaknesses associated with this timing.¹¹ We also explain how some of the proposed reforms may reduce the weaknesses.

2.4.1 Morning: Trade agreement

A cash investor and a collateral provider typically agree on a tri-party repo before 10 AM. Anecdotal evidence suggests that 90 to 95 percent of a dealer's tri-party repos are arranged before that time. Some smaller dealers report arranging all their tri-party repo funding between 8 and 8:30 AM. The agreement specifies the amount of cash the investor will provide, the interest rate, and the term of the repo. The acceptable collateral for an agreement also comes out of the appendix to the tri-party custodial agreement. The majority of tri-party repos are believed to be overnight or "open" repos. Open repos roll over by default, unless one of the parties explicitly chooses to cancel the transaction. Some repos have terms such as one week, two weeks, a month, or even longer. The lack of knowledge related to the fraction of overnight, open, and term repos is related to the fact that the clearing banks themselves did not need to know the term of the tri-party repos they were settling, for reasons we describe below. The haircut that applies to a particular collateral class is not negotiated at the trade

¹¹The report of the Task Force on Tri-Party Repo Infrastructure is available at http://www.newyorkfed.org/prc/report_100517.pdf. The Federal Reserve Bank of New York released a white paper commenting on the report and describing the weaknesses in that market. The white paper is available at http://www.newyorkfed.org/banking/nyfrb_triparty_whitepaper.pdf

level but, instead, is specified in the appendix of the custodial agreement between the three parties. Hence, changing haircuts requires amending the agreement.

A trade agreed upon in the morning does not settle until the afternoon, around 5 PM. Prior to the reforms, the clearing banks were not systematically notified of the agreement between the collateral provider and the cash investor at the time it occurred in the morning. Instead, the clearing banks would receive this information later in the day, before the time the repo would settle. Even then, the term of the repo may not have always been specified.

There was also some uncertainty regarding the time at which the trade was legally binding. Some market participants appeared to believe that the trade was binding at the time of the agreement, in the morning, while others appeared to believe that the trade was binding only at the time of the settlement, in the afternoon. The proposed reforms clarify that the trade is legally binding at the time it is agreed upon and require confirmation of all trades to all parties, including the clearing bank, shortly thereafter.

2.4.2 Afternoon: Collateral allocation

In the afternoon, after the close of Fedwire[®] Securities Service and the Depository Trust & Clearing Corporation (DTCC), the collateral provider knows the composition of its portfolio, since securities can no longer be traded. With this information, and with the information provided by the cash investors regarding the amount of financing they will provide and the securities they will accept as collateral, the dealers can allocate acceptable collateral to each trade using clearing-bank provided optimization tools. These tools can determine the most effective allocation of the available securities, taking into account the investors' acceptable collateral and the haircut specified in the custodial agreement.

The need to know the haircuts for the collateral allocation is the reason they are specified in the appendix of the custodial agreement. Negotiating haircuts at the trade level would make the allocation of collateral much more complicated. Table 1 represents three stylized and hypothetical collateral schedules between a cash investor and a collateral provider. The

first schedule applies to tri-party repos that must be backed by Agency collateral or collateral of better quality. For such repos, Treasuries, Agency debentures, and Agency MBS are acceptable and each would carry a haircut of 2 percent. Corporate bond or equities would not be acceptable collateral. The second schedule applies to tri-party repo contract that must be backed by corporate bond or collateral of better quality. In this case, Treasuries, Agency debentures, and Agency MBS are considered better collateral, but equities are not. The haircut on corporate bonds would be 5 percent in this example, while the haircut on the other collateral classes would remain 2 percent. The third schedule applies to tri-party repo contract that must be backed by equities or collateral of better quality. Again, in this case Treasuries, Agency debentures, and Agency MBS are considered better collateral. However, corporate bonds are not acceptable. This hypothetical example is meant to illustrate that while there may be no disagreement that Agency securities are of higher quality than corporate bonds and equities, the relative ranking of corporate bonds and equity may not be clear cut. In some cases, equity may be acceptable but not corporate bonds, while in other cases the reverse may be true.

Table 1: Hypothetical haircut schedules

Agencies		Corporate bonds		Equities	
Collateral class	haircut	Collateral class	haircut	Collateral class	haircut
Treasuries	102%	Treasuries	102%	Treasuries	102%
Agency debentures	102%	Agency debentures	102%	Agency debentures	102%
Agency MBS	102%	Agency MBS	102%	Agency MBS	102%
Corporate bonds	No	Corporate bonds	105%	Corporate bonds	No
Equities	No	Equities	No	Equities	108%

Depending on the asset classes a cash investor is willing to accept, an actual schedule could have many more categories, including international agencies, municipal securities, private label MBS, or asset backed securities. Several sub-categories might exist for each of these broad categories.¹²

¹²Appendix B provides an extensive list of collateral that is, or has been, acceptable in the tri-party repo market.

The settlement of the initial leg of the repo trade occurs on the books of the clearing banks in the afternoon. Balances are transferred from the investor's balances account to the collateral provider's balances account, while securities are transferred from the collateral provider's securities account to the cash investor's securities account. This allows the collateral allocation for tri-party repo trades to occur after the close of the Fedwire[®] Securities wire, which occurs at 3:30 PM, and the close of DTC, which occurs at 4:30 PM. In contrast, settlement of DvP repos must occur before the close of the securities wire or DTC.

2.4.3 Next morning: The “unwind”

Between 8 and 8:30 AM the next morning, the clearing banks “unwind” the tri-party repo trades. The unwind consists of sending the balances back to the investor's balances account and the securities back to the collateral provider's securities account on the balance sheet of the clearing bank. At the same time, the clearing banks extend intraday credit to the dealer since the securities are no longer financed by the tri-party investors.

All repos are unwound, including terms repos and open repos that are rolled over, because the unwind is mainly done for operational ease. In addition, because of the lack of three-way trade confirmation noted above, the clearing banks may not have known the term of the repo transactions they were facilitating. For non-maturing trades, an alternative way to think of the unwind is that clearing banks extend intraday credit to dealers and dealers substitute the cash for the securities as collateral to the repo. Term trades are “rewound” every evening, at the same time as the initial leg of new repos are settled. Reallocating collateral for term-trades may be desirable even if the clearing bank did not extend intraday credit to the dealers. Tri-party repo is considered “general collateral” financing, meaning that an investor may care about the class of collateral it receives, but not about the specific issue. Hence, the optimal collateralization of a trade could vary from day to day, or even intraday, as the dealer's portfolio of securities changes.

The unwind is important because collateral providers need access to their securities during

the day for their business activities. Unwinding the repos makes collateral substitutions easier. Indeed, it is operationally complicated to substitute collateral in the cash investor's account at the clearing bank, especially for securities that are traded often, such as Treasuries. It is more convenient to substitute collateral on the dealer's account at the clearing bank. The clearing bank has access to the whole pool of securities for each dealer, rather than the subset that each investor takes as collateral. In addition, the dealer may keep in custody at the clearing bank securities that are not financed through tri-party repos. The clearing banks employ a risk management concept called Net Free Equity (NFE) to ensure that the value assigned to the dealer's securities on their book exceeds the value of the intraday loan. Using NFE, the clearing banks can allow collateral providers to buy and sell securities in an operationally efficient manner.

It is important to highlight that the unwind is at the discretion of the clearing bank. This was not well understood by some market participants before the crisis. Some cash investors believed that the unwind would always occur, even during times of stress. Instead, the clearing bank has the contractual right to refuse to unwind the repos of a collateral provider. For example, if a clearing bank felt that a dealer might have to declare bankruptcy during the day, it could choose to protect itself by not unwinding. Practically speaking, refusing to unwind the repos of a dealer would almost certainly force that dealer into default. Without access to its securities, the dealer would be unable to perform its business. If the unwind did not occur, the investors would find themselves holding securities that they may have to liquidate. In particular, some money market mutual funds are allowed to take as collateral securities that they cannot hold on their balance sheet. These securities would have to be liquidated quickly. Moreover, some money fund shareholders may be concerned with the risk facing their fund in such a situation and could seek to redeem their shares, triggering a run on the fund.

Many cash investors leave the balances they have received after the unwind in their account at the clearing bank during the day. This could be because they have no use for the balances. In some cases, dealers have an arrangement with cash investors to leave the balances in their

account at the clearing banks. The clearing banks charge dealers for daylight overdrafts, so the dealers have an incentive to offer favorable terms to a cash investor who leaves its balances at the clearing banks during the day. The clearing banks also benefit as it reduces their need for intraday reserves, which they otherwise may have to obtain from the Federal Reserve at a small cost.¹³ A consequence of the unwind is to shift the exposure of cash investors from many smaller secured exposures to various collateral providers to a large unsecured exposure to one or two clearing banks. Some cash investors have mentioned preferring not to have such an exposure to a clearing bank intraday.

Once the balances have been sent back to the cash investors, the collateral providers no longer have funding for their securities. One of the services provided by the clearing banks is intraday funding for the collateral providers' securities. The unwind, and the provision of intraday credit by the clearing banks, introduce fragility into the tri-party repo market in a number of ways. First, the unwind makes it easier for cash investors to pull their funds from the tri-party repo market, potentially exacerbating the risk of runs. Second, the exposure to a dealer default shifts from the investors overnight to the clearing banks intraday, potentially creating perverse incentives to be the first to pull away from a troubled dealer. Third, the extension of intraday credit by the clearing banks is a source of fragility both to themselves and to the collateral providers that rely on them for their funding. We discuss these sources of fragility in more detail in section 4.

One of the major operational improvements from the reforms is the aim to achieve the "practical elimination" of the extension of intraday credit by the clearing banks. The long run objective is the elimination of the routine daily unwind of all repo trades. This could be made possible by technology that permits the substitution of securities collateral in real time in the cash investors' accounts. A related improvement is the transition to one daily settlement time for both legs of repos, rather than one settlement time in the evening for initial leg and one settlement time in the morning for the closing leg. More immediately, a reduction in intraday

¹³The clearings bank would breach their daylight overdraft caps should a sufficiently large share of the tri-party investors' cash be withdrawn.

credit extended can be achieved by no longer unwinding term and rolling open repos.

When repos are unwound early in the morning between 8 and 8:30 AM, the clearing banks have little or no information regarding a collateral provider's ability to obtain funding in the afternoon. This makes the decision to unwind and extend intraday credit to the dealer more risky. If, instead, the closing leg of maturing repos is settled at the same time as the opening leg of new repos, the clearing banks would know if a dealer has enough funding before they make the decision to settle maturing repos.

3 The tri-party repo market during a (relatively) stable period: July 2009 - January 2010

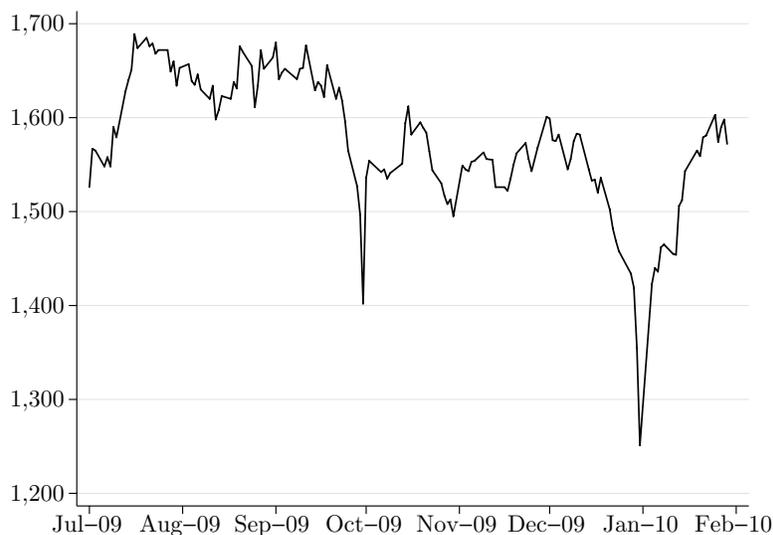
In this section, we first describe our data. We then present statistics that describe the tri-party repo market over a relatively stable period, from July 1, 2009, to January 27, 2010. By starting the sample in July 2009, we hope to be sufficiently far removed from the height of the crisis in the fall of 2008. We do not extend the sample too far into 2010 as the market is likely to change under the influence of the reforms proposed by the Task Force on Tri-Party Repo Infrastructure. In section 5 we examine the market from July 1, 2008 to June 30, 2009, with the goal of understanding dealer and investor behavior at the height of the financial crisis.¹⁴

3.1 The data

The Federal Reserve Bank of New York collects data on the tri-party repo market. The data to which we have access are the quantity and type of collateral posted in this market and the haircuts associated with various types of collateral. These data are not the universe of dealers and investors, but rather all the major players, whom account for the vast majority of tri-party repo activity. For each dealer, we observe the daily total value of cash borrowed and

¹⁴Some of the most dramatic events in the tri-party repo market occurred between September 2007 and July 2008, in particular before March 17, 2008, when the PDCF was introduced. Unfortunately, we do not have data covering that period.

Figure 1: Tri-Party Repo Market Size (\$ billions)



collateral provided by asset class. Using these values we can calculate, for each dealer, the average haircut by asset class. For investors, we have the data in two different forms. For those investors on one clearing bank, denoted clearing bank A, we know the joint distribution of collateral and investors. For each of these investors, we observe the daily total value of collateral accepted by asset class. For those investors on the other clearing bank, denoted clearing bank B, we know the joint distribution of investors and dealers. For each dealer, we observe the daily total amount of cash lent by investor. Both the investor and dealer data are at a daily frequency, from July 1, 2008 to January 27, 2010.

3.2 Overview

From July 2009 to January 2010, the mean daily amount of collateral posted in the tri-party repo market was more than \$1.5 trillion (see Figure 1), down from a high of \$2.8 trillion in April 2008 (FRBNY 2010). The daily amount funded in tri-party repo is fairly stable over this time period, although there are large drops in activity at quarter ends. While banks finance a

Table 2: Composition of Tri-Party Repo Collateral (percent)

Fed-eligible collateral	Agency Debentures	11.4
	Agency MBS	36.3
	Agency Remic	4.6
	Ginnie Mae MBS Pools	1.2
	Ginnie Mae REMICs	0.3
	US Treasuries and Strips	28.9
	sub-total	82.7
Non Fed-eligible collateral	Asset Backed Securities	2.4
	Commercial Paper	0.3
	Corporate Bonds	5.9
	DTC-Other	0.4
	Equity	4.0
	Money Market	1.6
	Municipal Bonds	0.7
	Other	0.1
	Private Label CMO	2.0
	Whole Loans	0.1
sub-total	17.5	

Note: Numbers may not sum to 100 because of rounding.

large variety of assets through this market, Agency mortgage-backed securities (MBS), Agency debentures, and US Treasuries and Strips account for more than three-quarters of the total value of all collateral posted over this time (see Table 2).

From July 2009 to January 2010, there were 26 dealers borrowing cash in our data. While the majority are primary dealers, hedge funds and other institutions with large portfolios of securities also participate. The collateral provider side of the tri-party repo market is concentrated, with the top 5 dealers accounting for 57% of borrowing in our data and the top 10 accounting for 88%. While the majority of borrowing is collateralized by just three types of assets, the typical dealer uses 10 types of assets¹⁵ as collateral.

¹⁵We use a generalized definition of type of asset consistent with the categories presented in table 2 plus a category for cash as collateral.

Collateral providers tend to borrow from a number of investors. Using the investor data from clearing bank B, we find that the top 5 dealers have an average of 40 investors each. Yet dealers still rely significantly on specific investors; for the top 5 dealers, the largest investor's share of a dealer's overall borrowing is 19%. Not surprisingly, dealers which borrow smaller amounts have fewer investors. The median number of investors for the five dealers who borrow the smallest amounts is 1.¹⁶

On the investor side of the tri-party repo market, our data includes observations from 241 investors between July 2009 and January 2010. Like the dealer side, there is concentration in the investor side of the tri-party repo market. The largest 10 investors account for 59% of the lending in our data. In contrast to the dealer side, there is a long tail of small investors. Investors lend to a number of dealers. Using the investor data from clearing bank B, we find that the largest number of dealers to which an investor loaned cash on a single day was 8. Small investors, which make up the majority of the investors in our data but account for only a small fraction of the cash lent, generally lend to a single dealer. The value-weighted median number of dealers to which an investor will lend cash on a single day is 5. These statistics on the number of dealers to which an investor will lend are understated, however, since they are based on data from one clearing bank and the larger cash investors are active on both clearing banks.

3.3 Variables in a tri-party transaction

A tri-party repo trade consists of five key variables: the interest rate, the haircut, the size of the transaction, the type of collateral and the maturity date. The schedules of haircuts applicable to a repo are determined beforehand when two parties and the clearing bank sign a custodial agreement. Thus, at the time of the trade, dealers and investors only need to agree on the

¹⁶The composition of dealers for each clearing bank differ slightly. While each clearing bank had the same number of dealers from July 1, 2009 to January 27, 2010, the average dealer on one clearing bank provided about twice as much collateral in tri-party repo than the average dealer on the other clearing bank. These differences in dealer composition should be kept in mind when considering statistics based on activity on one clearing bank.

other four variables. We have a wealth of information on haircuts and transaction volumes by collateral type. Unfortunately, we only have aggregate interest rate data on repos and no information on the term of transactions. Industry contacts report, however, that the largest tenor of triparty repo agreements are overnight.¹⁷ We begin by presenting stylized facts on interest rates and then examine the behavior of haircuts.

3.3.1 Interest Rates

Our interest rate data comes from Bloomberg and provides an overview of the interest rates paid on tri-party repo and DvP repos. Further, our interest rate data is limited to repos where Treasuries, Agency Debentures and Agency MBS securities were used as collateral.

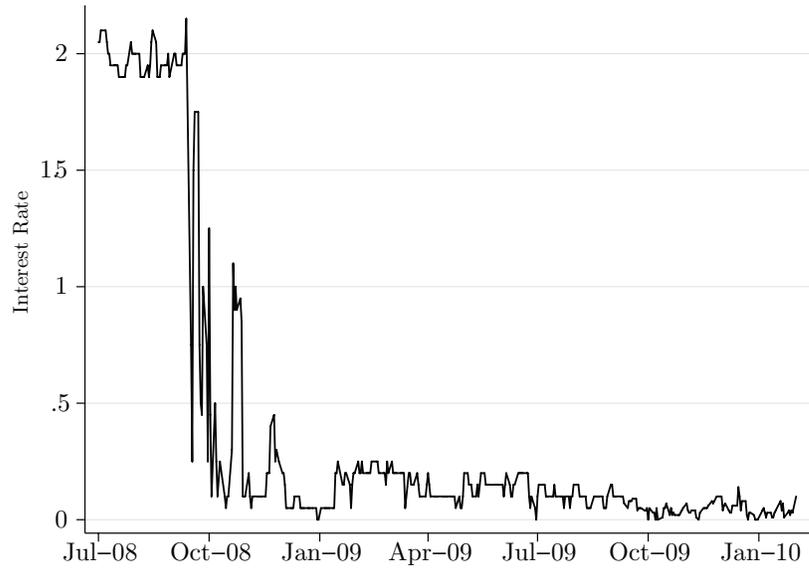
The data show that Treasury, Agency Debentures and Agency MBS repo rates declined over our sample period as the Federal Reserve lowered the federal funds rate. Figure 2 plots the average interest rate for overnight Treasury repos, and shows its dramatic decline from over 2 percent in 2008 to below 25 basis points in 2009. The interest rates for overnight Agency Debentures and Agency MBS repos closely followed those for Treasury repos. Figure 3 plots the spread between Agency Debentures and Agency MBS repos and Treasury repos, all of which have an overnight maturity. As the figure illustrates, except for the period after the Lehman Brothers bankruptcy, interest rates for these different repos rarely diverged.¹⁸

The movement of interest rates in the Bloomberg data is consistent with what we observe in separate data provided to us by a large investor in tri-party repo. That proprietary data shows a fall in rates for Treasury, Agency Debentures and Agency MBS tri-party repos that closely mimics the Bloomberg data. Further, there is a lot of volatility in interest rates for a short period of time after the bankruptcy of Lehman Brothers. Keeping these general stylized facts in mind, we now examine haircuts in the tri-party repo market.

¹⁷For example, FitchRatings Fund & Asset Manager Rating Group reports in their Money Market Funds U.S.A. Special Report (Oct. 4, 2010) that 81.8% of repo allocations by Fitch-Rated taxable money market funds as of August 31, 2010 were overnight.

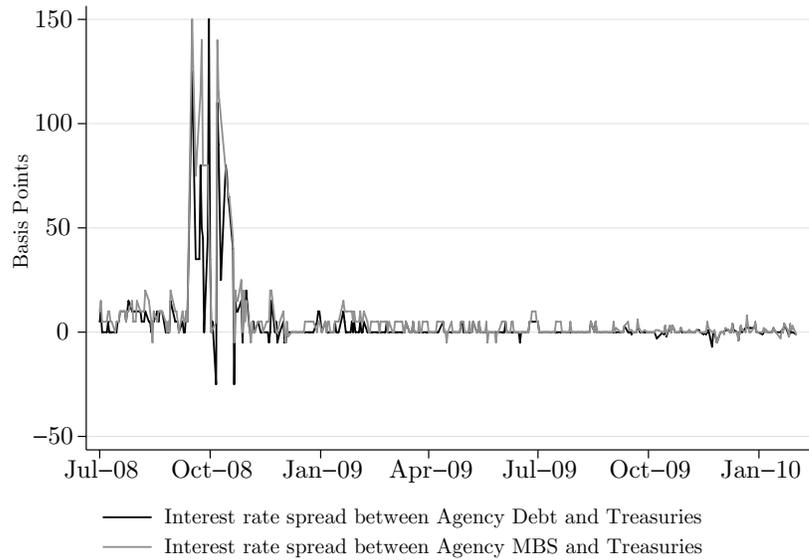
¹⁸The Lehman Brothers holding company (LBHI) declared bankruptcy on September 15, 2008. For more details see section 5.1.

Figure 2: Overnight Treasury Repos



Note: Data is from Bloomberg

Figure 3: Spread between Overnight Agency MBS, Agency Debentures and Treasury Repos



Note: Data is from Bloomberg

3.3.2 Haircuts

If the dealer defaults on its repo agreement, the collateral securing the transaction at least partially protects the cash investor from losses. Collateral does not always fully protect the investor because the market value of collateral can vary over time. The haircut on a repo transaction, which measures how much a repo transaction is over-collateralized, is a way for a cash investor to minimize losses from liquidating collateral in the event of default.¹⁹ When negotiating haircuts, in principle the cash investor is concerned about the liquidity of the underlying collateral. Predicting the market value of underlying collateral in case of default is not easy, and likely depends on a variety of factors.

In tri-party repo, we believe there are three main drivers behind the setting of haircuts. First, haircuts differ across collateral types in relation to the volatility in the value of the collateral. We expect asset classes with greater volatility to exhibit higher haircuts, so as to protect the cash investor from large downward swings in the market value of the collateral. Second, haircuts differ across collateral types in relation to their underlying liquidity. The liquidity of an asset class plays a role in the formulation of haircuts, because more liquid securities are easier to sell quickly, more able to absorb a large increase in supply and thus less prone to fire-sale prices and large losses that can be associated with a large dealer defaulting. Therefore, collateral which is considered more liquid will typically receive lower haircuts. Third, because haircuts only come into play when a dealer defaults, haircuts vary across dealers according to perceptions about each dealer's probability of default.

From our discussions with industry participants, we learned that investors are quite heterogeneous with respect to the use of haircuts. Some investors accept a variety of collateral and seem to set haircuts according to the three drivers mentioned above. Other investors seek to only trade with dealers for which the probability of default is perceived to be zero. For these cases, the haircut is not relevant and so are simply set to a uniform level across asset classes. Taken to the extreme, the risk management strategy of these investors treats tri-party

¹⁹Garbade (2006) provides a history of repo contracting conventions in the U.S.

Table 3: Tri-Party Repo Haircuts

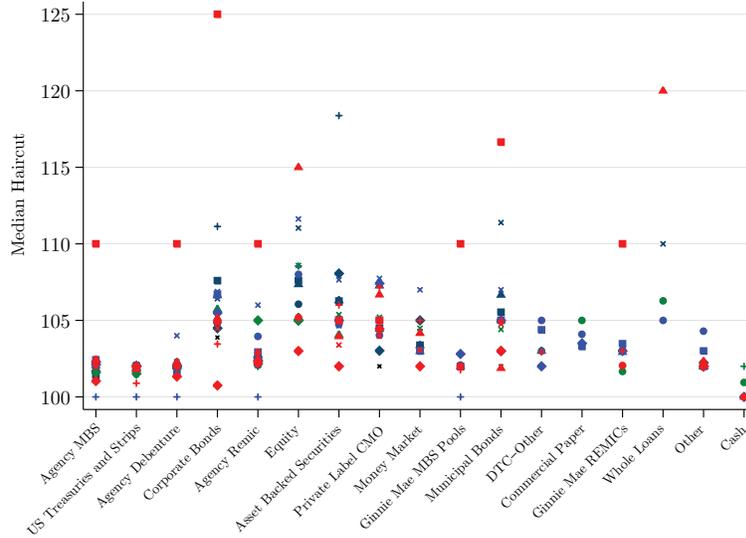
Fed-eligible collateral	Agency Debentures	102.1
	Agency MBS	102.0
	Agency Remic	102.7
	Ginnie Mae MBS Pools	102.1
	Ginnie Mae REMICs	103.0
	US Treasuries and Strips	101.7
	sub-total	102.3
Non Fed-eligible collateral	Asset Backed Securities	106.5
	Commercial Paper	103.7
	Corporate Bonds	106.0
	DTC-Other	103.4
	Equity	107.3
	Money Market	104.0
	Municipal Bonds	105.6
	Other	102.2
	Private Label CMO	108.4
	Whole Loans	110.0
sub-total	105.7	
All		104.4

Note: Average haircuts computed over July 2009 to January 2010. Fed-eligible securities are securities that can be settled on the Fedwire[®] Securities Service, while Non-Fed eligible, also called DTC-eligible, can be settled by the Depository Trust Company (DTC).

repo transactions as unsecured loans. Investors also differ in their ability to handle and sell different collateral types. Some investors, for example, refuse to accept certain types of collateral (i.e. the haircut is equal to 100%) because liquidating such collateral would be very costly for them.

In the data we find that haircuts differ quite a bit across collateral type; Table 3 lists the average haircut by collateral type over the July 2009 to January 2010 period. As expected, the more liquid securities, such as US Treasuries, Agency Debentures, and Agency MBS, have lower haircuts relative to the more illiquid securities, such as Asset Backed Securities and Corporate Bonds.

Figure 4: Median Dealer Haircuts by Asset Class



Note: A median haircut over 150 for Private Label CMO is not shown. Each dealer is assigned a different color-symbol combination which is consistent across asset classes. The asset classes are ordered from left to right by total volume over the sample.

There is also large variation in haircuts across dealers. In Figure 4 we show the average haircuts by dealer and asset class. Two features stand out: First, there is substantial heterogeneity in the haircuts dealers face, even for highly liquid assets such as US Treasuries. Second, some dealers face high haircuts relative to their peers across all asset classes. This figure suggests that differences among dealers is an important factor in the setting of haircuts.

An additional item of note is that haircuts on cash collateral are not zero for all dealers. Cash is sometimes included in a tri-party repo if a dealer does not have enough securities to pledge as collateral, for example because fails were higher than expected. Cash, which is usually borrowed from the clearing bank, would then make the difference between the value of the available securities and the amount of the repo. The fact that the haircut on cash is not always zero may be due to investors that assign the same haircut to all asset classes, consistent with the idea that some investors do not actively manage haircuts. It could also be the result

of cash not being a perfect security.²⁰ Consequently, investors could charge a non-zero haircut in hopes of discouraging the use of cash collateral. In practice, cash collateral is rarely used in tri-party repo (see figure 32).

Table 3 and Figure 4 demonstrate that haircuts substantially vary both across collateral types and dealers. We explore to what degree differences in assets or dealers are driving the level of haircuts by regressing haircuts on dummies for asset classes and for dealers and comparing the estimated coefficients. In Table 4 we report the estimated coefficients, where dealers and assets have both been ranked from the largest to smallest coefficient.

The range of the estimated coefficients on both the dealer and asset dummies are of similar magnitude. This result suggests that a dealer's reputation (i.e. its probability of default) has roughly equal importance as the collateral when determining haircuts in tri-party repo. Given the existence of collateral, the importance of counterparty risk may seem surprising. The importance of the counterparty, however, has been highlighted by market participants. For example, "Craig Delany, a managing director at JPMorgan's Investment Bank, however, stated that, in triparty repos, typically investors look to the counterparty (i.e., broker dealer) first and the collateral second when setting haircuts. In other words, a haircut may not be sufficient for an investor if it has serious concerns about the viability of its counterparty" (Valukas 2010).

Besides differences in perceived possibilities of default, one possible driver of differences in haircuts across dealers could be a dealer's size. Because dealers differ in terms of their presence in tri-party repo, we also explore if larger dealers negotiate smaller or larger haircuts. A priori, it is not clear whether dealers with a larger market share would have larger or smaller haircuts. Haircuts should be increasing in the amount of collateral an investor expects a dealer to bring to the market, all else equal. After all, if a dealer is financing a large amount of repos with a specific asset, then if this dealer defaults there will be a huge supply of that asset on the market. All of this dealer's investors, then, will face difficulties liquidating that asset at

²⁰Perfecting a security means that a party has taken all the legal steps necessary to establish a lien against the security. This is straightforward to do with non-cash collateral, and more difficult to accomplish with cash collateral.

Table 4: Coefficients on Haircut Decomposition

Variable	Coefficient		Variable	Coefficient	
	estimate	std. err		estimate	std. err
dealer 1	0.90	0.15	Agency MBS	0.03	0.09
dealer 2	0.92	0.30	Agency Debenture	0.12	0.09
dealer 3	0.97	0.26	Other	0.55	0.10
dealer 4	1.44	0.30	Ginnie Mae MBS Pools	0.57	0.12
dealer 5	1.46	0.18	Agency Remic	0.72	0.09
dealer 6	1.54	0.15	Ginnie Mae REMICs	1.17	0.13
dealer 7	1.61	0.38	DTC-Other	1.82	0.13
dealer 8	1.65	0.15	Commercial Paper	1.90	0.21
dealer 9	1.66	0.15	Money Market	2.18	0.12
dealer 10	1.67	0.16	Municipal Bonds	3.62	0.11
dealer 11	1.75	0.23	Corporate Bonds	3.90	0.09
dealer 12	1.82	0.29	Asset Backed Securities	4.14	0.10
dealer 13	1.98	0.30	Equity	5.00	0.11
dealer 14	2.04	0.31	Private Label CMO	5.97	0.10
dealer 15	2.04	0.31	Whole Loans	8.51	0.21
dealer 16	2.14	0.15			
dealer 17	2.39	0.29	constant	99.32	0.29
dealer 18	2.44	0.29	clrbnk	0.64	0.25
dealer 19	2.55	0.30			
dealer 20	2.84	0.29			
dealer 21	2.90	0.31			
dealer 22	3.07	0.29			
dealer 23	4.63	0.32			
dealer 24	9.18	0.22			
dealer 25	10.75	0.30			

Note: clrbnk is a dummy variable equal to 1 for trades settled by one of the clearing banks. The dealer with the lowest average haircuts and US Treasuries and Strips were the excluded dummies for dealer and asset classes, respectively.

non-fire sale prices. On the other hand, dealers who are considered safer may negotiate lower haircuts and then use tri-party repo to a larger extent relative to their risky peers. In this case, dealers with a larger market share would be associated with lower haircuts.

We use regression analysis to measure the correlation between haircuts and dealer size. We construct two measures of a dealer's size. First, we take the ratio of a dealer's share of collateral by asset class and clearing bank, which captures a dealer's size conditional on an asset class. Second, we construct a ratio of the dealer's share of all collateral by clearing bank, which measures a dealer's size in the overall market. We then regress haircuts on the log of each ratio, controlling for clearing bank and each collateral asset class. The results indicate that both measures are statistically correlated with haircuts, but only the measure of dealer size relative to all collateral provided is economically meaningful (see Table 5). The estimated coefficient implies that a one percent increase in a dealer's share of all collateral posted at a clearing bank is associated with a 50 basis point decrease in haircuts. We interpret these estimated coefficients to say that dealers with whom investors require low haircuts use tri-party repo as a source of financing more often than those dealers with whom investors require high haircuts. This observation is also consistent with the idea that some dealers are perceived to be "too big to fail" (TBTF). Such a dealer would be able to obtain large amounts of funding at a lower cost than other dealers that are not perceived to be TBTF. This funding advantage would give incentives for the dealer to take large positions.

3.4 Dealer-Investor relationships

In addition to the haircuts and other components of a tri-party repo transaction, an important issue in this market is the dynamics of the relationship between dealers and investors. Do dealers look for new investors from one day to the next, or does a dealer typically roll over its tri-party repo agreements with an investor? This is particularly important in this market because it is decentralized and all trades are struck on a bilateral basis.

In this section we distinguish "Standard" and "Specialty" dealers based on the number of

Table 5: Coefficients on Market Size and Haircuts

Variable	Parameter	
	estimate	std err
Dealer-Asset	0.043	0.012
Dealer-Market	-0.494	0.019
clrbnk	-0.440	0.052
constant	102.955	0.054

Note: ‘Dealer-Asset’ is the log of a dealer’s share of collateral by asset class and clearing bank, ‘Dealer-Market’ is the log of a dealer’s share of all collateral provided by clearing bank, and ‘clrbnk’ is a dummy variable equal to 1 for trades settled on one of the clearing banks. Not reported but also included are fixed effects for each asset class of collateral.

investors and amount of securities financed. Relative to the Standard dealer, Specialty dealers are smaller in size, have fewer investors, and often are not financing tri-party repo’s mainstay securities of Treasuries, Agency Debentures and Agency MBS.²¹ The typical Standard dealer finances about \$97 billion a day in tri-party repo, compared to only \$1 billion for the Specialty dealer. Since a typical Standard dealer posts \$100 billion dollars of securities in this market each day, the stability of a relationship between a dealer and an investor over time plays a key role in the efficiency of the tri-party repo market. For example, if the investor-dealer relationship is stable, there is less risk that a dealer will be unable to obtain financing and leave the clearing bank exposed due to the morning unwind.

We examine the persistence of the relationships between dealers and investors, focusing on daily changes. As expected, we find a high degree of persistence; dealers often borrow the same amount of cash from an investor from one day to the next, providing the same types of assets as collateral.

To measure the persistence of the dealer-investor relationship, we would ideally want data on the amount dealers borrow from investors by collateral type. Because we do not have this data, we examine the dynamics of the relationship between dealers and investors from three different viewpoints. We start by looking at dealers and the day-to-day change in the collateral

²¹Standard dealers account for 77 percent of the observations in the data.

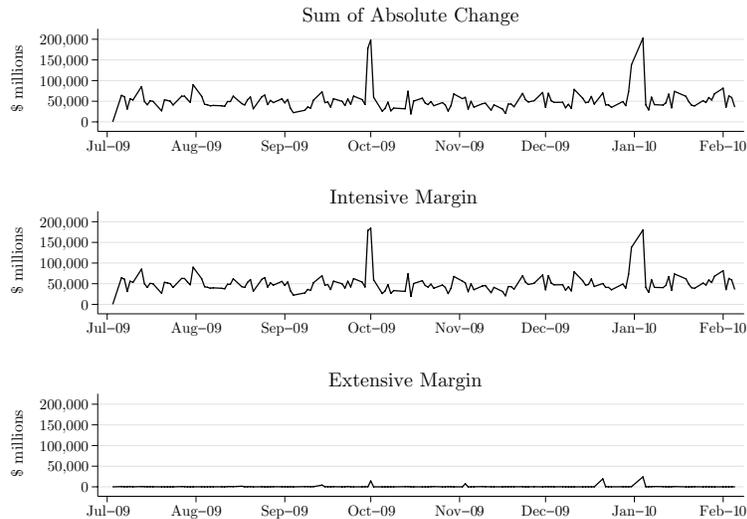
they post. We then look at investors and the day-to-day change in the collateral they accept. Finally, we look at the investor data from clearing bank B, where we observe the total amount of cash a dealer borrows from a specific investor.

As seen in Figure 1, the aggregate amount of collateral dealers post in the tri-party repo market is fairly consistent from day to day. This suggests the market is relatively stable, in that dealers are able to finance a similar amount of securities from one day to the next. To better understand the changes in collateral posted, we decompose this daily change into an extensive and intensive margin. Changes in the extensive margin reflect the dealer no longer financing an asset class from the previous day or beginning to finance an asset class that was not financed the previous day. Changes on the intensive margin correspond to changes in the value of collateral posted for an asset class, conditional on the dealer posting collateral in the same asset class on the previous business day.²² We take the absolute value of these changes and sum across dealers to analyze which margin drives the changes in collateral posted. In the top panel of Figure 5 we plot the absolute value of the daily change in collateral, summed across dealers. Then in the bottom two panels of Figure 5, we plot the decomposition of these changes into the intensive and extensive margins. These figures clearly show that the intensive margin drives the daily change in collateral posted. Hence, dealers typically finance the same asset classes in tri-party but change the exact daily amount of each asset class.

A problem with measuring the extensive and intensive margins is that our data mixes overnight and term lending. Because of term loans, investors may require more than one day to terminate lending to a dealer. For these cases, only the last day of lending would be attributed to the extensive margin. To address this issue, we look more closely at changes on the intensive margin. Specifically, large changes on the intensive margin would signal that investors and dealers are not rolling over their trades from one day to the next, but continually juggling their financing.

²²A dealer could be financing the same portfolio of securities every day, but changes in the market prices of this portfolio could result in differing valuations of the portfolio each day that we would observe as changes on the intensive margin.

Figure 5: Absolute Daily Changes for All Dealers



For each dealer, we look at the daily value of collateral posted and the daily change in collateral posted.²³ We report the results in Table 6, where we have divided dealers into Standard and Specialty groups. The top panel of Table 6 described the distribution of collateral posted by dealers while the middle and bottom panels describe the distribution of the day-to-day change in collateral posted by dealers.

For both Standard and Specialty dealers there is little variation in the amount of collateral financed. To measure how much dealers alter the amount of collateral they post in the short term, for each dealer we construct the difference between the (i) 75th and 25th, (ii) 90th and 10th, and (iii) 99th and 1st percentiles of the amount of securities financed for each month between July 2009 and January 2010. These three measures capture the variation in the amount of financing a dealer seeks within a month. In the top panel of Table 6 we report the average of each measure for both types of dealers across the months of July 2009 to January 2010. For Standard dealers, the average difference between the 75th and 25th quartiles in a given

²³If a dealer exited the market on a particular day, the change on market value would be a missing value. By and large, only small dealers did not consistently finance securities in tri-party repo in our sample.

month is \$5.6 billion, a fairly small difference given that the typical Standard dealer finances almost \$100 billion. Looking at the tails of the distribution reinforces the claim that dealers borrow consistent sums in the short term. Indeed, for the (90th,10th) and (99th,1th) percentile measures, the average difference is \$10 and \$15 billion, respectively. Similar results hold for Specialty dealers, suggesting that within a given month, dealers only rarely decide to substantially change how much they finance in tri-party repo. One exception to this occurs at the end of quarters, as seen in Figure 1. These declines in tri-party volume are likely driven by window-dressing prior to quarterly reporting dates by dealers.

Reinforcing this point, the daily change in total securities that Standard dealers finance ticked up about \$6 million a day, or 0.02 percent (see the middle and bottom panels of Table 6). Looking at day-to-day changes, we see a fairly steady amount of securities being financed. Indeed, the difference between the 75th and 25th quartile on the distribution of the daily change in collateral posted is \$4 billion, a paltry 5 percent of the median value of a typical dealer's securities. Turning to the tails of the distribution, the difference between the 99th and 1st percentiles is \$15 billion. Once again, given the almost \$100 billion of collateral posted on the tri-party repo market by the average dealer, there is relatively little day-to-day variation in the amount a dealer finances.

Finally, we also compute the daily change in the amount a dealer finances for each asset class. This might be important, because in reaction to negative news, an investor may ask for higher quality collateral. Hence, a dealer still might borrow the same amount of cash from day-to-day, but be required to post higher quality collateral. For the most part, even at this level of detail, there is little day-to-day change in the amount financed. The median daily change is \$0, and the difference between the 75th and 25th quartiles on the distribution of the daily change in securities financed is \$180 million, about 7 percent of the average value invested at the dealer-asset class level. Unlike at the dealer level, however, we do see more dramatic changes in the tail of the distribution. The difference between the 99th and 1st percentiles is \$1.1 billion, or 43 percent of the average amount financed at the dealer-asset class level.

Table 6: Statistics on Dealer's Daily Aggregate Position by Size

Statistic	Dealer Type	
	Standard	Specialty
<i>Distribution of Collateral Posted (\$million)</i>		
Median	97,000	1,110
75th - 25th	5,550	149
90th - 10th	9,820	318
99th - 1st	15,300	508
<i>Distribution of the Daily Change in Collateral Posted (\$million)</i>		
Median	6	0
75th - 25th	4,080	31
90th - 10th	8,210	143
99th - 1st	14,600	530
<i>Distribution of the Daily Change in Collateral Posted (ratio)</i>		
Median	1.000	1.000
75th - 25th	0.049	0.018
90th - 10th	0.092	0.086
99th - 1st	0.190	0.156

Note: The statistics "Xth - Yth" denote the difference of the Yth percentile from the Xth percentile of the relevant distribution for a dealer in a given month. The results reported are an average across the months of July 2009 to January 2010.

The above analysis confirms that dealers typically borrow the roughly same amount from day-to-day, and do so using essentially the same portfolio of general collateral. Hence there is substantial stability on the dealer-side of the market from day-to-day, implying a predictable amount of securities are supplied to the tri-party repo market. Nevertheless, these statistics do not directly address the investor's side of the market. Do investors typically lend to the same set of dealers? To answer this question, we first examine whether investors invest the same amount of cash from day-to-day, using all our investor data. Next, using a subset of the data from one clearing bank, we examine whether investors loan the same amount to a dealer from day-to-day.

Given the heterogeneity on the investor side, we group investors into quartiles based on the daily amount invested. We look first at investors grouped by amount invested. For the group of smallest investors, the typical total cash amount loaned is \$13 million a day (see Table 7). In contrast, for the largest investor group, the typical investor loans \$19 billion a day. Like dealers, investors do not often significantly change the amount they invest in the tri-party repo market from day-to-day. For all groups of investors, the median change in amount invested is \$0, and the difference between the 75th and 25th quartiles on the distribution of the daily change in amount invested is a small amount for each investor group. Unlike dealers, however, we do see large changes in the amount loaned from day-to-day in the tail of the distribution. With the exception of the smallest investors, the difference between 90th and 10th percentiles as well as the 99th and 1st percentiles is fairly large both in level and percentage terms (see the middle and bottom panels of Table 7). Hence, investors do make large changes to the amount of cash they lend in tri-party repo, albeit rarely.

Interestingly, the smallest group of investors acts quite differently from larger investors, and provide extraordinarily stable funding. One explanation for this difference could be the predictability of payment flows for smaller investors relative to larger investors. If payment flows are more predictable for smaller investors, it could be easier for them to select the amount they would like to continually roll over in tri-party or to use term contracts versus overnight

Table 7: Statistics on Investor's Daily Aggregate Position by Size

Statistic	Firm Size (from low to high)			
	Quartile 1	Quartile 2	Quartile 3	Quartile 4
<i>Distribution of Daily Amount Invested (\$million)</i>				
Median	13.3	200	1,180	19,000
75th - 25th	0.051	34	175	1,630
90th - 10th	0.120	73	331	3,080
99th - 1st	0.268	100	530	4,380
<i>Distribution of the Change in Daily Amount Invested (\$million)</i>				
Median	0	0	0	0
75th - 25th	0	11	54	980
90th - 10th	0	50	200	2,230
99th - 1st	0	125	478	4,430
<i>Distribution of the Change in Daily Amount Invested (ratio)</i>				
Median	1.000	1.000	1.000	1.000
75th - 25th	0.000	0.060	0.042	0.052
90th - 10th	0.000	0.257	0.161	0.119
99th - 1st	0.066	0.610	0.451	0.229

Note: The statistics "Xth - Yth" denote the difference of the Yth percentile from the Xth percentile of the relevant distribution for an investor in a given month. The results reported are an average across the months of July 2009 to January 2010.

deals.

Looking further into the stability of the investor-dealer relationship, we examine the investor data from clearing bank B, which links investors and dealers. We compute the same type of statistics described previously, and report them conditioning on the size of the investor-dealer relationship. The smallest investor-dealer trades average \$40 million, while the largest average \$3 billion (see the top panel of Table 8). Our measures of stability in funding mimic those computed for investors overall. The typical investor-dealer relationship is stable the majority of the time. While not commonplace, there are large daily changes in the amount loaned. Looking at the distribution of the change in the daily amount invested, the difference between the 90th and 10th percentiles is about 15 percent of the median amount invested (see the middle and bottom panels of Table 8).

An exception to the stability of funding at an investor-dealer level around September 15, 2008, when Lehman Brothers declared bankruptcy. During that time, the number of investors Lehman receives cash from declines precipitously. We take a closer look at the tri-party repo market during the height of the financial crisis in section 5.

Overall the data suggest dealers and investors form long-term relationships where repos do not change much on a daily basis. In times of stability, dealers are usually posting the same amount of collateral and investors are lending the same amount of cash. Further, the day-to-day change in collateral posted and cash lent is remarkably small in most cases. There are, however, unusual instances where there are large changes in the amount of cash lent (and so collateral posted). While some of these instances of large changes in tri-party volume may be routine (e.g. end of quarter effects by dealers), other instances may be related to concerns about counterparty or credit risk.

4 Fragility in the tri-party repo market

The FRBNY white paper notes three weaknesses of the tri-party repo market: 1) the market's reliance on intraday clearing bank credit, 2) the pro-cyclicality of risk management practices,

Table 8: Statistics on Borrowing at the Investor-Dealer Level, by Investor Size

Statistic	Firm Size (from low to high)			
	Quartile 1	Quartile 2	Quartile 3	Quartile 4
<i>Distribution of Daily Amount Invested (\$million)</i>				
Median	40	250	850	3,270
75th - 25th	0.0	38	100	485
90th - 10th	0.2	75	200	895
99th - 1st	0.4	119	335	1,310
<i>Distribution of the Change in Daily Amount Invested (\$million)</i>				
Median	0	0	0	0
75th - 25th	0	6	0	90
90th - 10th	0	41	100	500
99th - 1st	0.5	125	400	1,440
<i>Distribution of the Change in Daily Amount Invested (ratio)</i>				
Median	1.000	1.000	1.000	1.000
75th - 25th	0.000	0.026	0.000	0.029
90th - 10th	0.000	0.177	0.135	0.142
99th - 1st	.087	0.570	0.487	0.382

Note: The statistics “Xth - Yth” denote the difference of the Yth percentile from the Xth percentile of the relevant distribution for an investor in a given month. The results reported are an average across the months of July 2009 to January 2010.

3) the lack of effective and transparent plans to support orderly liquidation of a defaulted dealer's collateral. During the crisis, a concern was that investor's confidence in the market may erode to the point that they would no longer want to finance any dealer through tri-party repo. In this section, we focus more specifically on the fragility introduced by the reliance on intraday credit from the clearing bank.

4.1 The risk of investor runs

The similarities between financing securities with repo contracts and banking have been pointed out in several papers (see Duffie 2010, Gorton and Metrick 2009, Martin, Skeie, and von Thadden 2010). These papers suggest that repos could be subject to the risk of runs, similar to those that threaten banks. Some papers, such as Gorton and Metrick (2009) emphasize the risk of "haircut spirals" similar to the phenomenon described in Geanakoplos (2003) or Brunnermeier and Pedersen (2009). In contrast, Duffie (2010) and Martin, Skeie, and von Thadden (2010) describe runs that are similar to standard bank runs. In this section, and in section 5, we provide evidence that runs in the tri-party repo market resemble standard bank runs, and are thus different from runs in other repo markets. Several features of the tri-party repo market before the reforms made it particularly susceptible to runs; some are related to the nature and behavior of the cash investors while others are related to the mechanics of the tri-party repo market.

As noted previously, some tri-party repo investors focus on the quality of their counterparty first, rather than the collateral. These investors would prefer to withdraw their funding to a troubled dealer even against high quality securities. This is what happened to Bear Stearns as "repo market lenders declined to roll over or renew repo loans, even when the loans were supported by high-quality collateral such as agency securities" (Friedman 2010). It may seem surprising that investors would refuse to finance high-quality securities since the risk of loss appears to be very small and, in any case, the investor could increase margins to protect itself. There is, however, some uncertainty associated with the process of taking possession of the

collateral and liquidating it. A security that is virtually free of credit risk, such as an agency security, may still be subject to liquidity, market, or interest rate risk. Even if this risk is very small, an investor would likely prefer to invest in a safe rather than a troubled collateral provider (see also Duffie 2010). Some investors lacked expertise of access to liquidity that would have facilitated an orderly liquidation of collateral. For such investors, the risks were not negligible.

In addition, major categories of tri-party repo investors, such as money market mutual funds and commingled securities lending cash reinvestment pools, have to worry that they may face withdrawal pressures from their own investors. As a result, they are very intolerant of liquidity and credit risk. Upon learning that a money fund in which they have invested is financing a dealer perceived to be having creditworthiness issues or was financing a dealer now in default, these investors may preemptively withdraw their funds, regardless of the risk that liquidating the collateral actually represents. This “headline” risk, the risk that a money fund may find itself in the headline of a news story, is another reason why money funds may prefer not to finance a dealer, even against high quality collateral.

While investors could ask for higher haircuts to protect themselves, we show in section 5 that haircuts in the tri-party repo market barely increased during the crisis. This suggests that the tri-party repo market did not experience the type of margin spirals described theoretically in Geanakoplos (2003) or Brunnermeier and Pedersen (2009). Instead, a run in the tri-party repo market appears more likely to look like a run on a bank.

4.1.1 The role of the morning unwind

Because of the unwind of all repos in the morning, assuming it occurs, cash investors who choose not to roll over their loans are protected from the consequence of their decisions. In other words, they are protected from the risk that the collateral provider is unable to roll over its financing. Assume a cash investor does not roll over its repo to the collateral provider. In such a case, the collateral provider must either find a new investor, liquidate some of its securities,

or default. If there were no unwind, then a cash investor that tried to withdraw its funding would only be able to do so if the dealer does not default. If the dealer did default, the cash investor would be unable to withdraw cash and would have to take possession of the collateral backing its repo. Since the decision to withdraw funding can be a contributing cause to the collateral provider's default, cash investors would be exposed to the risk they create when they try to withdraw funding. This may make cash investors more reluctant to invest in repos but, once they have made an investment, it could limit the risk that investors withdraw their funds precipitously.

Since there is a morning unwind, in contrast, the clearing bank assumes all the risk that the dealer cannot fund itself the next evening. Hence, once the unwind has occurred, cash investors with overnight or open repos face no risk if they choose to withdraw their funding. As such, they are in a situation that is similar to that of bank depositors, in many respects. The unwind is also likely to reduce the investors' incentives to monitor the dealer's quality, since the benefits of monitoring are shared with the clearing banks.

A simple model can illustrate the role of the unwind in exacerbating the fragility of the market.²⁴ Consider a hypothetical dealer that currently has three investors. Each investor provided financing for one period (last night) and must decide whether to re-invest with the dealer (tonight). Assume that the dealer survives if at least two investors re-invest. Otherwise the dealer defaults. The investors are identical. In making their decision to re-invest, the investors consider the following payoffs: An investor gets a payoff S , for 'success', if she invests and the dealer survives; O , for 'out', if she does not invest and is able to get her cash back; and F , for 'fail', if she invests but the dealer is forced to default or if she chooses not to invest but is unable to get her cash out. Whether an investor who does not want to re-invest is able to obtain its cash depends on the "microstructure" of the market, which is explored in details below. Assume $S > O > F$, which reflects the fact that, on the one hand, investors prefer to invest in a surviving dealers rather than keep their cash uninvited ($S > O$), and, on the other

²⁴Martin, Skeie, and von Thadden (2010) provide a more general model.

hand, investors prefer to hold cash rather than having invested in a failing dealer ($O > F$).²⁵

Consider the one-shot reinvestment game. Each investor chooses a strategy, either ‘invest’ or ‘not invest’, taking as given what other investors do. The focus is on the Nash equilibria in strategies that are not weakly dominated. A Nash equilibrium is a set of strategies, one for each investor, such that no investor has an incentive to unilaterally change her action. A strategy is weakly dominated if another strategy offers a payoff at least as large, or larger, for all actions of the other investors.

4.1.2 The tri-party repo market without unwind

In the tri-party repo market without unwind, the role of the clearing bank in allocating the collateral to different repos means that the investors do not face a “first-come-first-serve” constraint.²⁶ First, the clearing bank checks whether the dealer has enough funding to repay the previous day’s repos. If there is enough funding, then all the previous day’s repos are repaid simultaneously. If there is not enough funding, then the dealer must default and investors cannot get their cash.²⁷

Table 9 provides the payoffs of an investor, called investor I , in the case of the tri-party repo market without unwind. The top row indicates how many other investors re-invest and each cell shows the payoff of investor I , depending on her decision.

If no other investors re-invest, then the dealer must fail. Because there is no unwind, investor I cannot get her cash back if she tries not to reinvest. If one other investor re-invests, then the dealer succeeds if investor I re-invests and fails otherwise. Again, because there is no unwind, the investors hold the collateral in case of default. If both other investors re-invest, then the dealer survives no matter what investor I does. In particular, if investor I chooses not

²⁵This assumes that either the investors are not sufficiently collateralized or, even if the investor is sufficiently collateralized, that there are some expected costs associated with liquidating the collateral.

²⁶The case with a “first-come-first-serve” constraint, which may be applicable to the case of a dealer financing itself with bilateral repos, is considered in appendix D.

²⁷This situation is similar to the case of a firm rolling over a bond or commercial paper (CP) issue. Either the firm raises enough financing, and all bond or CP holders are repaid, or the firm is forced to default, and all bond or CP holders are treated equally in bankruptcy.

Table 9: Payoffs when there is no unwind

Other investors \Rightarrow	0	1	2
Invest	F	S	S
Not invest	F	F	O

Table 10: Payoffs when there is an unwind

Other investors \Rightarrow	0	1	2
Invest	F	S	S
Not invest	O	O	O

to re-invest, she gets her cash back.

Table 9 shows that ‘not invest’ is a weakly dominated strategy since, regardless of what other investors do, the payoff for investor I is at least as high when she chooses to invest and, in some cases, higher. Hence the only equilibrium is the one where all investors choose ‘invest’. In the game with no unwind, fragility due to pure coordination failures does not happen.

4.1.3 The tri-party repo market with unwind

If there is an unwind, the clearing bank returns the cash to all the investors before they need to make their decision to reinvest.²⁸ This implies that the investors have access to their cash if they choose not re-invest, regardless of whether the dealer survives. Table 10 provides the payoffs in the case with unwind.

With the unwind, an investor who chooses not to invest always gets her cash back. This is a key feature of the unwind: Investors are not subject to a “roll over” risk because they are no longer invested in the dealer at the time they make the choice to re-invest. The major impact of the unwind is that an investor is better off not investing if she believes that other dealers

²⁸This assumes that the clearing bank always unwinds. We do not consider the possible strategic interactions between the clearing bank and the investors. Martin, Skeie, and von Thadden (2010) consider these interactions further.

will not invest, since $O > F$. Hence, pure coordination failures are possible because it is an equilibrium for all investors not to invest. Of course, it is also an equilibrium for all investors to choose ‘invest’. The main message of this simple example is that the unwind introduces a source of fragility in the market.

The proposed reforms aim for the “practical elimination” of intraday credit provided by the clearing banks and, thus, of the unwind. The elimination of the unwind should improve the stability of the tri-party repo market by making investors bear some of the consequences of their decisions to withdraw funding. However, while this reform may reduce the risk of run, it will not eliminate it. Indeed, an investor that chooses to withdraw its funding because of concerns about a dealer may still be able to withdraw funding before the dealer defaults. This investor would be in a better position than investors that wait. In other words, the elimination of the unwind may eliminate the pure coordination runs as modeled by Diamond and Dybvig (1983) or Martin, Skeie, and von Thadden (2010). However, information based runs, of the type modeled by Chari and Jagannathan (1988) or Morris and Shin (2009) could still arise.

4.2 The hand-off of risk between investors and clearing banks

In addition to the risks noted in the previous section, the unwind can potentially create a perverse dynamic between investors and a clearing bank, which could result in a pull-back of funding to a collateral provider that is similar to a run. In the previous section, we assumed that the clearing bank would always unwind. However, a clearing bank may choose not to unwind the repos of a dealer if it fears that the dealer cannot obtain funding.

Every morning, the unwind transfers the risk of default of a dealer from the cash investors to the clearing bank. In the afternoon, the risk is transferred from the clearing bank to (a potentially new set of) cash investors, provided the dealer was able to obtain funding. This hand-off works well when all parties assume that the dealer will obtain financing, but could be problematic otherwise.

Assume that cash investors become concerned that the clearing banks may refuse to unwind

the repos of a dealer. The clearing bank may take this action because it does not want to be exposed to the dealer's failure if it occurs during the day. The investors realize that the dealer would almost certainly have to default if the clearing bank does not unwind its repos. Hence, the investors will be reluctant to provide repo financing to the dealer. Of course, the dealer would be forced to default if it is unable to obtain repo financing from the cash investors. So a clearing bank would not want to unwind the repos of a dealer that is not likely to obtain financing.

This dynamic is self-fulfilling in the sense that the reluctance of the clearing bank to unwind the repos of a given dealer creates the condition for investors not to want to provide repo funding to that dealer, which justifies the clearing bank's concerns. Similarly, the reluctance of cash investors to extend financing to a dealer creates the condition for the clearing bank to prefer not to unwind the dealer's repos, which justifies the investors' concerns.

The proposed reforms would address this risk with the elimination of the morning unwind. For example, if the closing leg of maturing repos is settled at the same time as the opening leg of new repos, then the hand-off of risk between investors and clearing banks is avoided. Hence, the type of "run" described in this section cannot occur. In particular, the introduction of collateral substitution mechanisms would allow collateral providers to have access to their securities while cash investors maintain a secured exposure to the collateral provider for the entire day.

4.3 The intraday exposure of the clearing banks

Another source of risk in tri-party repo is related to the intraday exposure of the clearing banks. Prior to the reforms, the two clearing banks would unwind all repos every morning, which implies a combined exposure of \$2.8 trillion at the peak of the market. While the size of the market has decreased, it is still above \$1.5 trillion. The exposures to individual collateral providers were also very large: the largest individual portfolio was over \$400 billion at the height of the market and some large dealers still finance more than \$200 billion in the tri-party

repo market.

This exposure implies that if a large collateral provider were to fail during the day, the clearing bank would have to take a massive amount of collateral on its balance sheet. This increase in the size of the clearing bank's balance sheet would have a negative impact on its regulatory capital ratio and could result in the bank becoming undercapitalized. In principle, most of the securities could be financed at the discount window, which limits the risk of a fire-sale of securities. Nevertheless, the clearing bank could face pressures to sell some of the assets quickly, to reduce the size of its balance sheet for example, and could be subject to interest rate or market risk.

The proposed reforms would address this risk with the “practical elimination” of intraday credit provided by the clearing banks. This should limiting the exposure of the clearing banks to a manageable level.

4.4 The risk to cash investors and collateral providers

The unwind has consequences for the cash investors that increase the fragility of the tri-party repo market. As noted earlier, during the day cash investors have a potentially large unsecured exposure to the clearing banks if they do not take the cash out of their accounts. This exposure could be a major concern if there are doubts about the health of a clearing bank. For that reason, cash investors could be hesitant to finance any of the collateral providers that count on this clearing bank to settle their tri-party repo. Hence, any concern with the health of the clearing banks could spread to dealers even if there are not doubts about their solvency. As noted above, the dealers are also exposed to the risk that the clearing bank may refuse to unwind their repos, which would almost certainly lead to the failure of the dealer.

These risks would also be mitigated by the “practical elimination” of intraday credit provided by the clearing banks. Cash investors would no longer have an unsecured exposure to the clearing bank and the clearing bank would not longer be in a position to have to decide whether or not to unwind the repos of a collateral provider. Nevertheless, some cash investors

may still be reluctant to finance the collateral providers who rely on a troubled clearing bank to settle their tri-party repos, particularly if the cash investors are concerned with “headline” risk.

5 The tri-party repo market during the crisis: July 2008 - July 2009

The vulnerabilities highlighted by the Task Force on Tri-Party Repo Infrastructure, and discussed in section 4, were a major source of policy concern during the crisis. Loss of funding in a market such as tri-party repo is part of the broader risk of runs on financial institutions in wholesale funding markets highlighted by the recent crisis. Duffie (2010) describes the mechanics of such runs. The consequences of a run in the tri-party repo market can be disastrous, as Bear Stearns experienced. In testimony before Congress, a Bear Stearns executive claimed that Bear Stearns suffered a run, of which a major component was the refusal of tri-party repo lenders to roll over or renew repo loans (Friedman 2010). Separately, Gorton and Metrick (2009) provides evidence of a system-wide “run” on an inter-dealer repo market.

We find little evidence of a market-wide run in the tri-party repo market. While the amount of collateral posted in tri-party repo did decline over the financial crisis, dealers still posted more than \$1.5 trillion in assets daily through July 2009. Further, we observe only small movements in median haircuts throughout the crisis. While Lehman Brothers experienced difficulties in the tri-party repo market, we find little evidence of runs on other individual dealers. In section 5.1 we examine in detail what happened to Lehman Brothers in the tri-party repo market around the time the Lehman Brothers Holding Company (LBHI) declared bankruptcy. In section 5.3 we compare the behavior of haircuts in the tri-party repo market with other repo haircuts during the crisis.

At its peak in April 2008, dealers posted \$2.7 trillion worth of collateral in the tri-party repo market. As the financial crisis progressed, activity in the tri-party repo market slowly declined

(see Figure 6). Nevertheless, dealers continued to post substantial levels of collateral in this market from July 2008 onwards. The composition of assets used as collateral has changed somewhat, with more liquid collateral being substituted for less liquid collateral. The amount of Non Fed-eligible collateral more than halved between July 2008 and July 2009, falling from \$600 billion to less than \$300 billion (see appendix E for figures showing the time-series of collateral value by asset type). Conversely, the amount of US Treasuries collateral stayed around \$500 billion over this period, perhaps because investors demanded higher quality, more liquid collateral as the financial crisis unfolded. Rather than reflecting problems with the tri-party repo market, we believe that the declines in collateral posted reflected a number of outside processes. These include: a general de-leveraging by dealers in response to the financial crisis; a shift to unsecured financing for some less liquid collateral; runoff caused by maturing assets and a decline in new issuance; declines in valuations that reduced the size of dealers' portfolios and the removal of Agency MBS securities through the Federal Reserve's Large Scale Asset Purchase (LSAP) program.²⁹

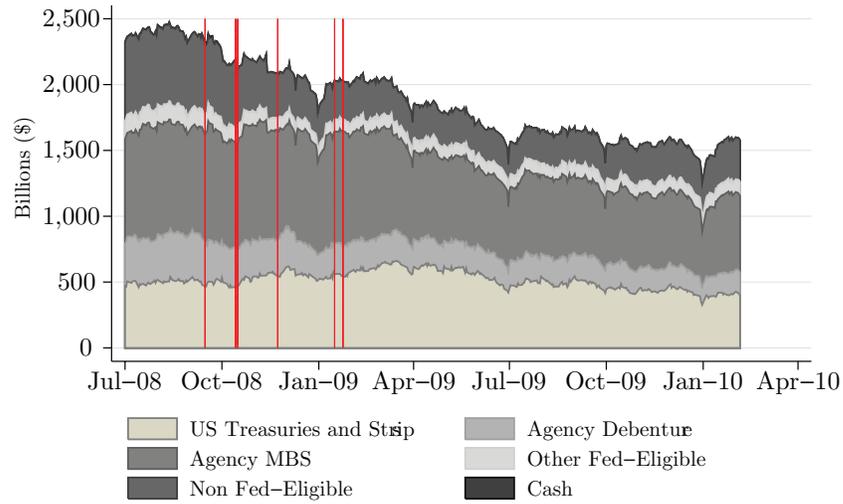
Consistent with this explanation, we find that the median haircuts for each asset type barely increased during the financial crisis (see Figure 7). For the three asset groups that make up the majority of collateral posted in this market - Treasuries, Agency Debentures and Agency MBS - haircuts hardly moved over the second half of the 2008.

In the next set of figures we plot six vertical lines marking significant adverse moments in the US financial system between July 2008 and June 2009. The six events are

- September 15, 2008: Lehman Brothers holding company files for bankruptcy.
- October 14, 2008: Nine large banks agree to receive capital injections from the Treasury.
- October 16, 2008: Swiss government provides capital injection to UBS, Swiss National Bank takes over portion of UBS's illiquid assets through an SPV.

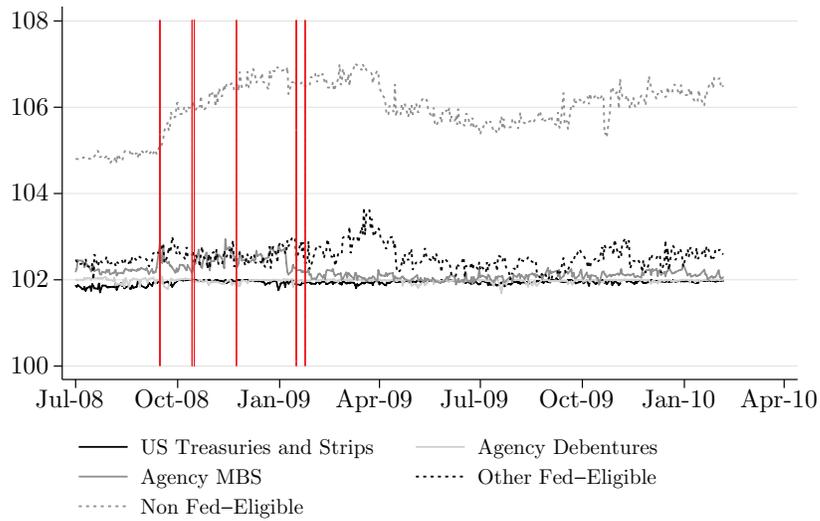
²⁹Background on the LSAP can be found at http://www.newyorkfed.org/markets/funding_archive/lsap.html.

Figure 6: Stacked Graph of Collateral



Note: July 17, 2008 excluded because no data was available for BNYM on that date.
 Red lines correspond to important market events. From left to right: 9/15/08 (Lehman),
 10/14/08 (9 banks receive aid), 10/16/08 (UBS), 11/23/08 (Citi), 1/16/09 (B of A), 1/24/09 (Citi).

Figure 7: Median Haircuts by Asset Type



Note: Red lines correspond to important market events. From left to right: 9/15/08 (Lehman),
 10/14/08 (9 banks receive aid), 10/16/08 (UBS), 11/23/08 (Citi), 1/16/09 (B of A), 1/24/09 (Citi).

- November 23, 2008: Citigroup receives assistance from Treasury and FDIC, with additional assistance from the Federal Reserve possible if necessary.
- January 16, 2009: The Federal Reserve, Treasury, and FDIC jointly aid Bank of America.
- January 24, 2009: Citigroup sells \$1.2 billion of government guaranteed bonds.

Looking at Figures 6 and 7, the Lehman Brothers bankruptcy, the first adverse event, seems to have the largest impact on volumes and haircuts. Collateral posted in the tri-party repo started its decline after the bankruptcy announcement alongside increases for haircuts on non-Fed-eligible collateral. However, the decline in collateral appears to be more of a gradual deleveraging (for reasons noted previously) rather than a sudden run. The large drop shortly after Lehman occurred at the end of a quarter, when perhaps dealers and investors were especially sensitive about the size of their balance sheets for quarterly reporting.

Another measure of the impact of the financial crisis on tri-party repo is the variation in haircuts across dealers over time. Interpreting changes in haircuts over time with our data is not straightforward because we observe the average haircut for a collateral type and dealer. Hence, the haircut is a weighted average of the distribution of haircuts a dealer faces from its investors, given a collateral type. Changes in this average haircut over time occur for three reasons. First, the dealer and investor may renegotiate the haircut schedule. Second, the composition of a dealer's investors may change, changing the applicable haircuts. Third, while not changing any of its repo agreements, the dealer could alter the portfolio of collateral it posts. For a given repo transaction, a dealer can almost always substitute higher quality collateral in lieu of the agreed upon collateral type (e.g. providing US Treasuries instead of Agency MBS). The haircut schedules agreed upon in the custodial agreement specify which substitutions are permissible and what is the applicable haircut (see the hypothetical haircut schedule in table 1). The substitution of higher quality collateral, all else equal, may change the average haircuts which we observe.

Nevertheless, changes in a dealer's average haircut over time do reflect a significant cost of funding to the dealer in the tri-party repo market. In times of uncertainty, this variation, or spread, in haircuts could go up if investors charge higher haircuts to dealers who are perceived to be riskier. To determine how the distribution of haircuts has changed over time, in Figures 8 through 11 we plot fan charts of haircuts for 4 general types of collateral.

The financial crisis did not have a consistent effect on the distribution of haircuts across different asset types. Looking at non-Fed-eligible collateral (Figure 11), we see the classic reaction to financial distress. Starting a month or so after the Lehman Brothers bankruptcy, the spread in haircuts dramatically expanded. The increase in the haircut spread was maintained through January 2009, before narrowing to its pre-Lehman Brothers bankruptcy levels. As we noted previously, alongside the increase in the haircut distribution, the median haircut rose and the amount of non-Fed-eligible collateral used in the tri-party repo market halved.

For Fed-eligible collateral, the financial crisis had differing effects on the distribution of haircuts across dealers. The haircut spread for US Treasuries increased, but was primarily driven by dealers facing *lower* haircuts than in the past (see Figure 8). Presumably, this lowering of haircuts during a time of crisis is a result of investors wanting higher quality, more liquid collateral (a flight to quality). The haircut spread for Agency Debentures also did not change much during the latter half of the financial crisis (see Figure 9). Like US Treasuries, a salient feature of the haircut spread is the occasional fall in haircuts faced by dealers. From January 2009 onwards, the distribution of haircuts across dealers tightens, perhaps in reaction to the LSAP program. Interestingly, the haircut spread for the 5th/95th and 10th/90th percentiles for Agency MBS began expanding prior to September 2008, but the median and spread between the 25th/75th percentiles increased at the time of Lehman's bankruptcy filing. Spreads began contracting somewhat in the latter months of 2008 before tightening up in January 2009 and beyond, similar to what is observed for Agency Debentures collateral.³⁰

The fan charts in Figures 8 through 11 demonstrate that dealers are quite heterogenous in

³⁰This tightening in haircut spreads is most likely due to the LSAP program as Agency securities have become more liquid.

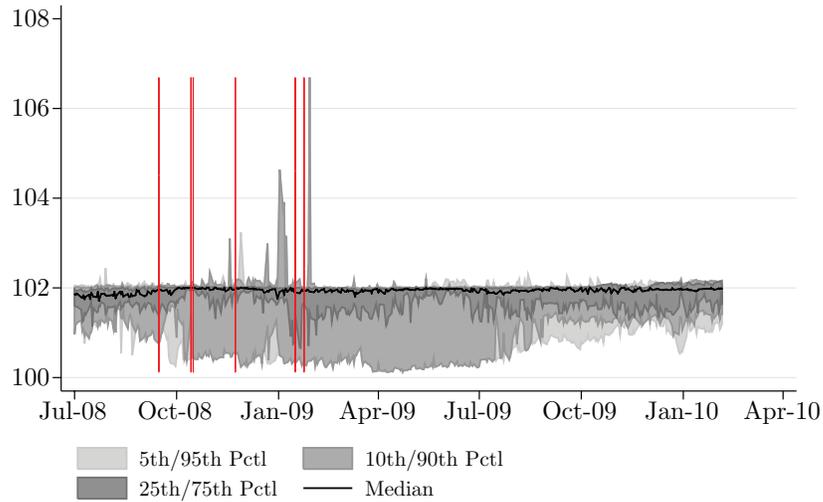
the haircuts they faced for a specific type of collateral over the financial crisis. Given these large differences in haircuts, how did dealers react? While we do not have information on the rates dealers negotiated, we do observe the amount of collateral they post. To analyze the co-movement of haircuts and volumes we first look at dealer behavior around the Lehman Brothers bankruptcy, which is arguably the most severe financial shock we observe in the data. In Figures 12 to 19 we present the level change in haircuts and the percent change in volumes around the Lehman Brothers bankruptcy for US Treasuries, Agency Debentures, Agency MBS, and Non Fed-eligible collateral. We compare the mean haircut and volume in the two months before and after the Lehman Brothers episode, excluding the week before and after Lehman declared bankruptcy. Across the 8 figures, each dealer has a unique color-symbol and the dealers are organized from the smallest to largest change in Treasury haircuts (see Figure 12). Note that percentage changes of -1 indicate that the dealer was active in that asset class in the early period and not active in the late period.³¹

Comparing dealers within and across collateral types, we do not see a consistent relationship between the changes in haircuts and volumes. We see dealers for which both haircuts and volume increase, some for which both haircuts and volume decrease, and some for which one increase while the other decrease (see appendix for figure 33, which plots changes in these two variables for each dealer and asset class). While we do not observe the interest rates dealers face, we believe a key driver behind the movement in haircuts and volume is a dealer's outside option. When dealers are able to find alternative sources of funding, we would expect to see increases in haircuts associated with decreases in volumes. When a dealer is under pressure from a variety of funding sources, the dealer may simply acquiesce to the higher haircuts and maintain or increase the collateral it posts.

To further explore the relationship between haircuts and volumes, we run a regression of the log of collateral value on the log of the associated haircut, with fixed effects for each dealer-asset class pair. When using data during the tri-party repo period of stability (July 2009

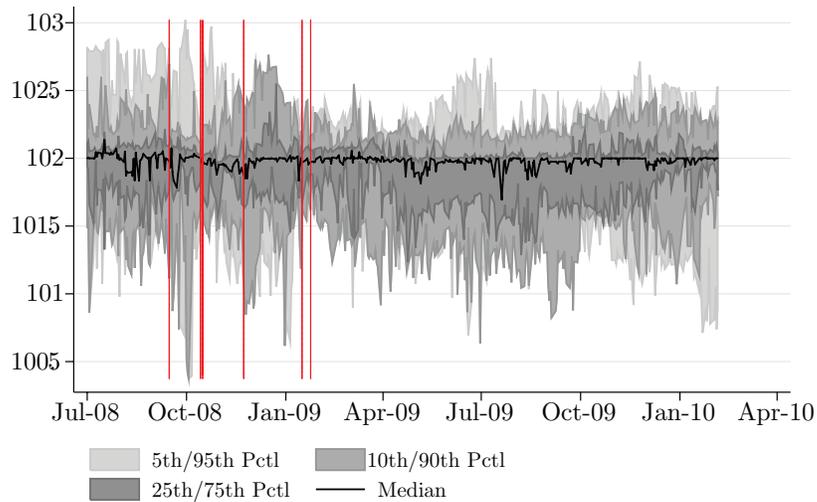
³¹There was only one dealer that entered an asset class (Non Fed-eligible) in the post-Lehman period that was not active in the pre-Lehman period. It was excluded from the Non Fed-eligible graph.

Figure 8: US Treasuries and Strips haircut fan chart (value-weighted)



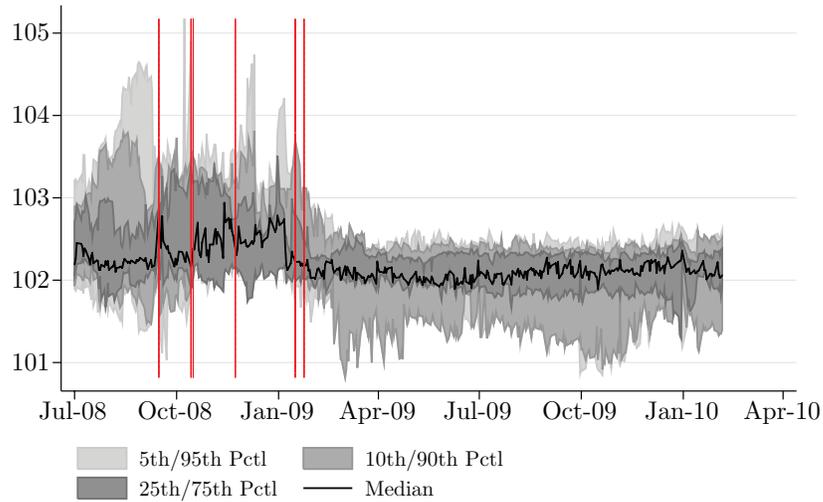
Note: July 17, 2008 excluded because no data was available for BNYM on that date.
 Red lines correspond to important market events. From left to right: 9/15/08 (Lehman),
 10/14/08 (9 banks receive aid), 10/16/08 (UBS), 11/23/08 (Citi), 1/16/09 (B of A), 1/24/09 (Citi).

Figure 9: Agency Debentures haircut fan chart (value-weighted)



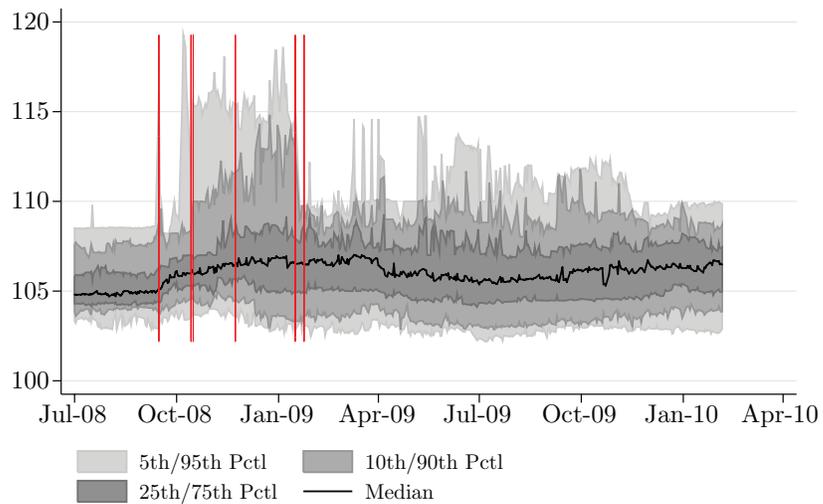
Note: July 17, 2008 excluded because no data was available for BNYM on that date.
 Red lines correspond to important market events. From left to right: 9/15/08 (Lehman),
 10/14/08 (9 banks receive aid), 10/16/08 (UBS), 11/23/08 (Citi), 1/16/09 (B of A), 1/24/09 (Citi).

Figure 10: Agency MBS haircut fan chart (value-weighted)



Note: July 17, 2008 excluded because no data was available for BNYM on that date.
 Red lines correspond to important market events. From left to right: 9/15/08 (Lehman),
 10/14/08 (9 banks receive aid), 10/16/08 (UBS), 11/23/08 (Citi), 1/16/09 (B of A), 1/24/09 (Citi).

Figure 11: NonFed Eligible haircut fan chart (value-weighted)



Note: July 17, 2008 excluded because no data was available for BNYM on that date.
 Red lines correspond to important market events. From left to right: 9/15/08 (Lehman),
 10/14/08 (9 banks receive aid), 10/16/08 (UBS), 11/23/08 (Citi), 1/16/09 (B of A), 1/24/09 (Citi).

Figure 12: Treasuries: Change in haircut.

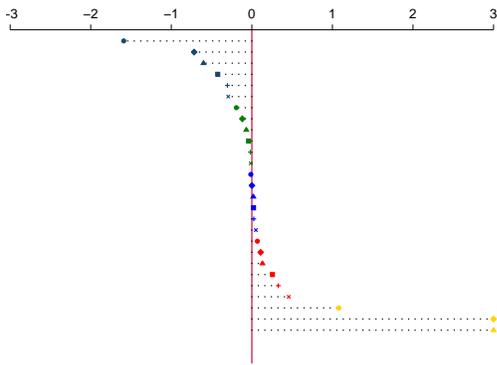


Figure 13: Treasuries: Change in volume.

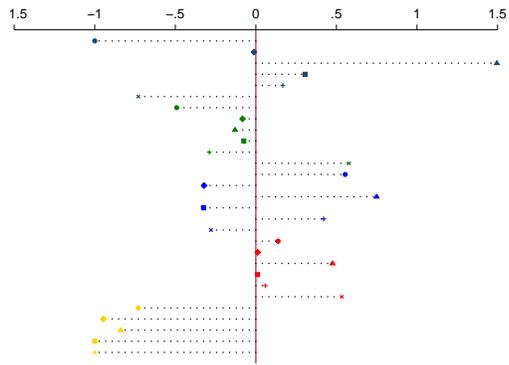


Figure 14: Agency Debentures: Change in haircut.

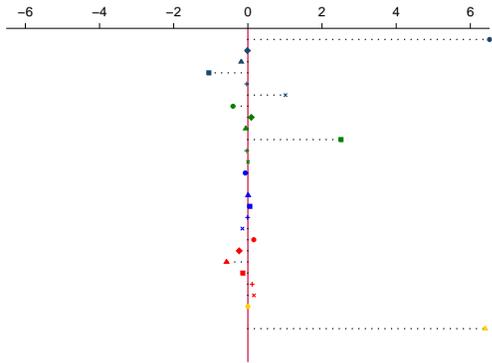
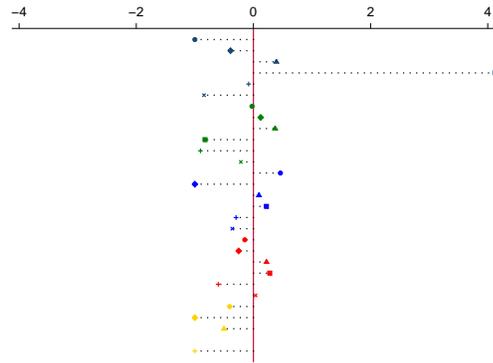


Figure 15: Agency Debentures: Change in volume.



to January 2010), the estimated coefficient on haircuts is equal to -1.613 and is statistically significant.³² Hence, a one percent increase in the haircut is associated with a 1.6 percent decrease in collateral posted. In contrast, when running the same regression on data during the financial crisis (July 2008 to July 2009), the estimated coefficient on haircuts is estimated to be 2.067 and is statistically significant.³³ Taken together, these regressions hint at the complicated relationship between haircuts and volumes in tri-party repo. We believe the sign on the estimated coefficients is different in the two periods because of dealers' outside options. During the periods of stability, dealers were able to find alternative sources of funding when faced with higher haircuts. During the crisis, dealers had few alternative sources of funding, and so did not decrease their borrowing when facing higher haircuts. However, we cannot rule out alternative theories, especially because we do not observe interest rates. Fully understanding participants' use of haircuts in tri-party repo alongside interest rates and volume is clearly an important issue, but one that we cannot study further without additional data.

5.1 Lehman Brothers Bankruptcy

The events leading to Lehman Brothers' bankruptcy have been described as a run (Morris and Shin 2009, Zubrow 2010). In this section, we take as given that Lehman Brothers faced a run and describe what happened to the firm in the tri-party repo market. We then examine whether other investment banks suffered while Lehman Brothers was failing and when dealers started to use the Primary Dealer Credit Facility (PDCF), a credit facility created by the FRNBY to backstop the tri-party repo market.

Because Lehman Brothers was active in many financial markets, our description is necessarily limited, but nevertheless informative about a failing dealer's actions in the tri-party repo market. A useful guide to the various ways a run may have affected Lehman Brothers' over

³²In this regression there are 29,507 observations and 264 fixed effect terms (i.e. dealer-asset class pairs). The R-squared term is 0.01

³³In this regression there are 55,092 observations and 331 fixed effect terms (i.e. dealer-asset class pairs). The R-squared term is 0.08

this time is given by Duffie (2010), which describes the mechanics of a dealer-bank failure. It should be noted that Lehman Brothers's holding company (LBHI) filed for bankruptcy on September 15, 2008, not the broker-dealer (LBI), the entity most active in the US tri-party repo market. LBHI filed a motion on September 17 to sell LBI to Barclays, and LBI was placed into SIPA proceedings on September 19, 2008. The case was transferred to the U.S. Bankruptcy Court on the same day and the sale was approved on September 20 (Crapo 2008).

In the week prior to the bankruptcy filing of the holding company, the value of Lehman's tri-party book and the number of investors declined dramatically. Lehman's total tri-party book fell from \$150 billion funded by over 60 investors on September 8, 2008, to \$95 billion funded by around 40 investors on September 12, the Friday before LBHI filed for bankruptcy (Figures 20 and 21). Nevertheless, Lehman closed Friday, September 12 meeting its secured financing requirements with no assistance from the PDCF. After the Holding company filed for bankruptcy on September 15, and given the significant amount of confusion and stress that ensued, Lehman had to rely on the PDCF to finance part of its tri-party repo book. Valukas (2010) reports that Lehman borrowed approximately \$28 billion at the PDCF on that day. Fewer than 20 investors engaged in tri-party repos with Lehman on Monday, September 15. These figures may even overstate investors' willingness to lend to Lehman Brothers. Since our data does not include the term of tri-party transactions, it is possible some of the investors that remained with Lehman were stuck in term trades and unable to pull back their funds without breaking legal contracts. Valukas (2010) reports \$21 billion in "mainly term repos" for that day.

The Valukas Report cites sources describing much of the decline in collateral posted in tri-party repo as part of a self-imposed trend, although there were additional declines that may have been unplanned (Valukas 2010). We can think of five reasons behind the decrease in collateral posted by Lehman Brothers in the tri-party repo market. First, investors in this market may have pulled back funding to protect themselves against the increased risk of Lehman Brothers defaulting. The Valukas Report notes that Fidelity, a large tri-party repo investor,

Figure 20: Lehman Brothers' Tri-Party Book

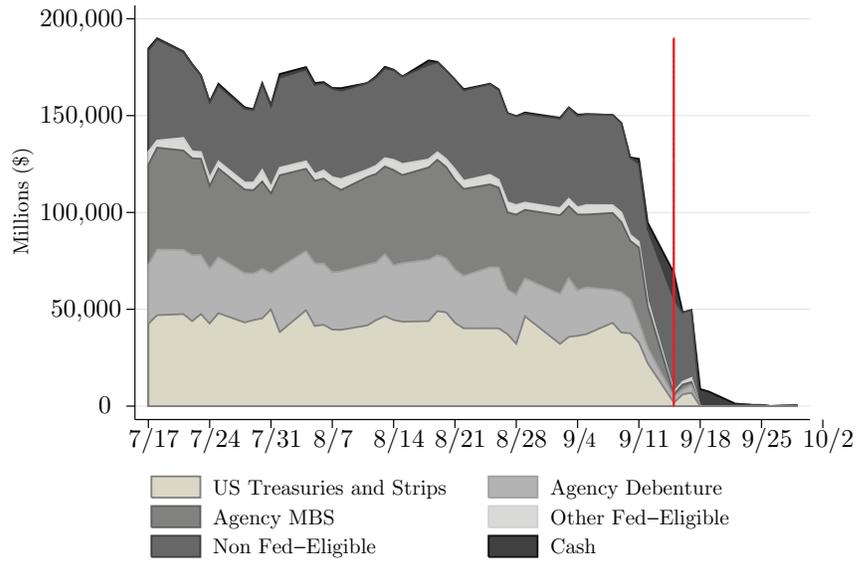
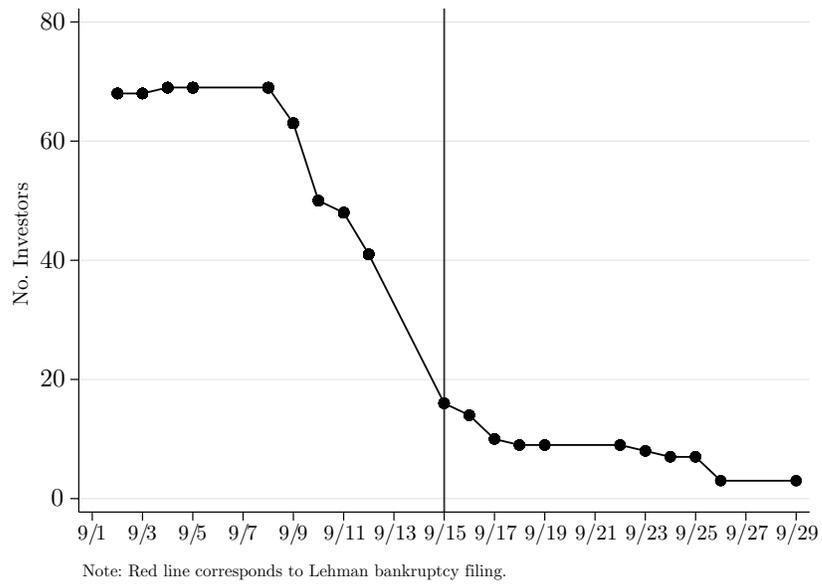


Figure 21: Number of Cash Investors in Lehman Brothers



“requested back” its overnight tri-party repo deals on September 12 (Valukas 2010). Hence, Lehman Brothers may have been forced to finance its securities in other markets (e.g. GCF repo[®] market described in section 2) or not at all. Second, Lehman Brothers was forced to post additional collateral with counterparties over this time, which may have reduced its tri-party repo portfolio. Third, in reaction to rumors of Lehman Brothers’ upcoming demise, hedge funds and other Lehman Brothers clients were moving their business to other broker-dealers, and thus withdrawing their collateral from Lehman Brothers. As described in Duffie (2010), losing these clients has a large impact on a dealer’s balance sheet. In particular, Lehman Brothers would have a smaller portfolio of securities to post as collateral in tri-party repo. Fourth, the wind down or deleveraging of the short dated (primarily overnight) matched books in Treasuries, Agencies, and Agency MBS likely played a part in the decline of tri-party funding over the course of the last few days before the actual bankruptcy. A similar deleveraging in other asset classes may have also played a role, albeit to a lesser extent. Fifth, and finally, in facing a run by investors, Lehman Brothers may have been selling collateral to raise money. Note, however, that since haircuts in tri-party are very small, the additional amount of money an institution can raise by selling an asset is small. For example, if the haircut on Treasuries is 2%, selling Treasuries only raises 2 additional cents for every dollar sold versus financing Treasuries in tri-party.

Alongside the decrease in collateral posted by Lehman Brothers, there was a shift in the composition of the portfolio of securities Lehman Brothers financed from high to low-quality collateral. From July 1, 2008 to September 1, 2008, 70% of Lehman’s tri-party book was financing Treasury, Agency Debentures and Agency MBS collateral. In the week prior to filing for bankruptcy, these collateral types made up 63% of Lehman’s book and only 11% for the week of September 15.³⁴ Coincidentally, the share of non Fed-eligible collateral increased dramatically, rising to 87% from about a quarter of Lehman’s tri-party collateral. Several of the

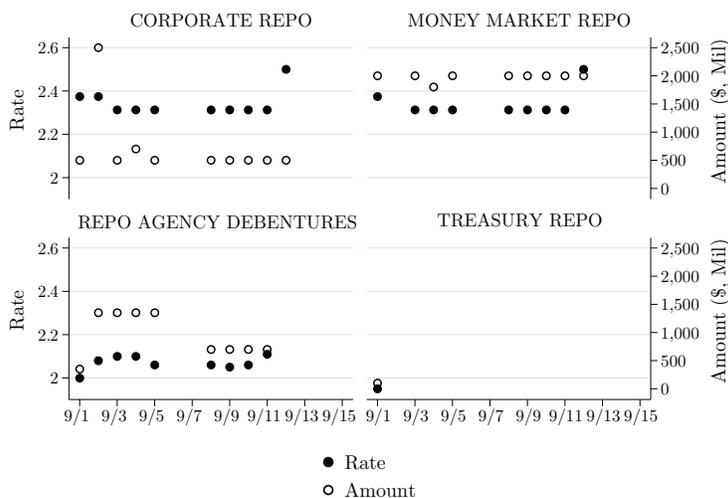
³⁴One reason for this dramatic decline may have been that some of these collateral types were funded outside of the tri-party repo market. For example, Lehman likely shifted some of its funding to repos settled by the FICC, which are blind brokered. GCF repos are included in tri-party but DvP repos settled by the FICC are not.

factors explaining the decrease in Lehman's overall portfolio may have affected Fed-eligible securities more than the less liquid asset classes. As a result, the share of Fed-eligible collateral could decrease.

With Lehman Brothers facing a run by investors, we expect this firm to face higher haircuts in the tri-party repo market. Haircuts, after all, protect investors from losses in the case of a dealer default. Surprisingly, alongside the dramatic decrease in collateral posted, Lehman Brothers did not face higher haircuts until just before it declared bankruptcy. Figure 23 illustrates that the median haircut Lehman Brothers faced in the two weeks before declaring bankruptcy was essentially flat until Thursday, September 11, two business days before declaring bankruptcy. This unresponsiveness of haircuts could reflect cash investors strategy of considering counterparty risk first and collateral risk second. Hence, rather than raise haircuts, cash investors may have simply refused to lend to Lehman Brothers. The rise in median haircuts on September 11 and 12 reflects higher haircuts across all collateral classes, but the average haircut increased the most for Agency MBS and non Fed-eligible collateral (see figure 24).

To gain a better understanding of the evolution of Lehman Brothers' relationship with tri-party repo cash investors while Lehman Brothers was facing a run, we examined data provided by a large cash investor. We look at haircuts, interest rates, and cash loaned to Lehman Brothers from September 1, 2008 to September 12, 2008, the last day this cash investor lent to Lehman Brothers. Over this period, the cash investor accepted Corporate Repo, Money Market Repo, Agency Debentures and Treasury Repo collateral from Lehman Brothers. Interestingly, the haircuts for each of these collateral types did not change: Agency debentures and Treasuries were charged a 2% haircut, while corporate and money market repo were charged a 5% haircut. Figure 22 displays the rates and volumes paid by Lehman Brothers by collateral type for this period. Surprisingly, there is very little movement on either dimension. Total volume invested fell by \$700 million, driven by an absence of a deal to finance the relatively high-quality Agency debentures on September 12. The average interest rate did slightly increase from

Figure 22: Rates Paid by Lehman Brothers in Tri-Party Repo



2.313 to 2.5 on September 12, based on cash loaned against Corporate and Money Market collateral. The rate increase is small in that it only cost Lehman Brothers about \$13,000.³⁵

In summary, during the time when Lehman Brothers faced a run by investors, the amount of collateral it financed in tri-party repo dramatically fell. Despite concerns about Lehman Brother’s solvency, the haircuts it faced in tri-party repo did not increase until two days before the holding company declared bankruptcy. Further, evidence from a large cash investor suggests that Lehman Brothers was not forced to pay dramatically higher interest rates.

When Lehman Brothers started to fail, a major concern for policy makers was the possibility that the disorderly liquidation of a failed dealer’s collateral would cause cash investors to become wary of tri-party repo, potentially making it difficult for other dealers to secure funding in that market. The presence of the PDCF appears to have helped stabilize the tri-party repo market. Whereas there had been no borrowing at the PDCF in the weeks prior to the Lehman bankruptcy, borrowing soared in the week following the bankruptcy. The aggre-

³⁵ $\$2,500,000,000 \left((1.025) \left(\frac{1}{360} \right) - (1.02313) \left(\frac{1}{360} \right) \right) = \$12,986.11.$

gate market value of collateral provided in tri-party, including the PDCF, dipped slightly but recovered quickly, falling from an average of \$2.38 trillion the three days prior to Lehman to \$2.31 on September 16, then returning to an average of \$2.36 trillion from September 17 to 19. The decline in Lehman's tri-party book accounted for 44% of the decline in the tri-party repo market on September 15, and the \$97.8 billion decline from September 9 to September 16 was larger than the decline in the entire tri-party repo market over the same period (\$74.8 billion). While haircuts for Lehman increased, median haircuts for other investment and commercial banks remained roughly constant in the weeks before and after Lehman's bankruptcy. Figure 23 displays the median effective haircut facing Lehman, commercial banks and investment banks.³⁶ It does seem clear that the Lehman bankruptcy did not trigger a run on the tri-party repo market as a whole, as volumes and haircuts for dealers other than Lehman did not change substantially.³⁷ Nevertheless, other dealers experienced stress during the following days. It also appears likely that stress in this market would have been considerably worse, absent the exceptional policy responses that took place, including the presence of the PDCF.

5.2 The role of the PDCF

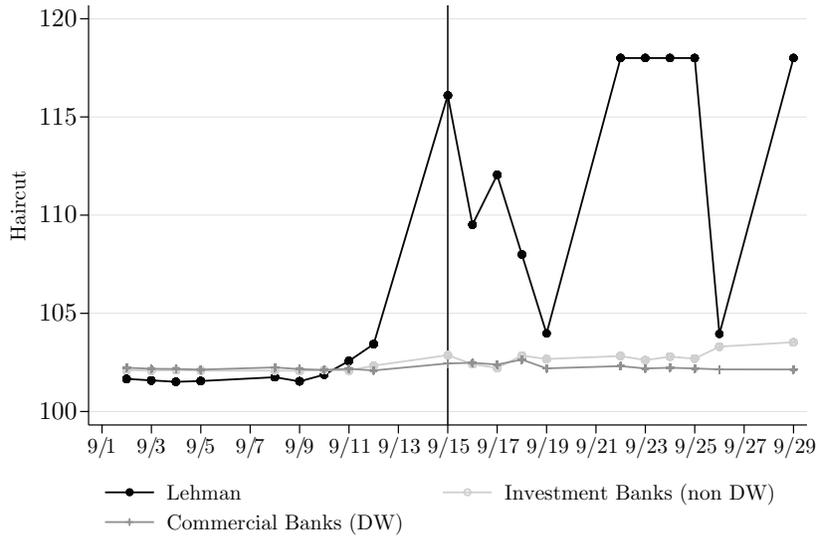
A number of cash investors and dealers have reported anecdotally that the PDCF was an important contributing factor to stabilizing the tri-party repo market. This could help explain the evidence provided in section 5 and suggests that the PDCF achieved its goal. Whatever role it played in stabilizing the market, the presence of the PDCF was not sufficient to prevent the dramatic reduction in Lehman's tri-party repo funding, discussed in section 5.1. Nevertheless, the PDCF may have prevented Lehman's trouble from spreading to other participants. In this section we discuss the role that the PDCF may have played in the tri-party repo market.

It is interesting to note that there was no lending at the PDCF in the weeks leading up to

³⁶Dealers classified as commercial banks were those with a connection to a commercial bank, which would have customer deposits that could potentially be used for funding, as well as access to the Discount Window. Investment banks were those without a corresponding commercial bank prior to August 2007.

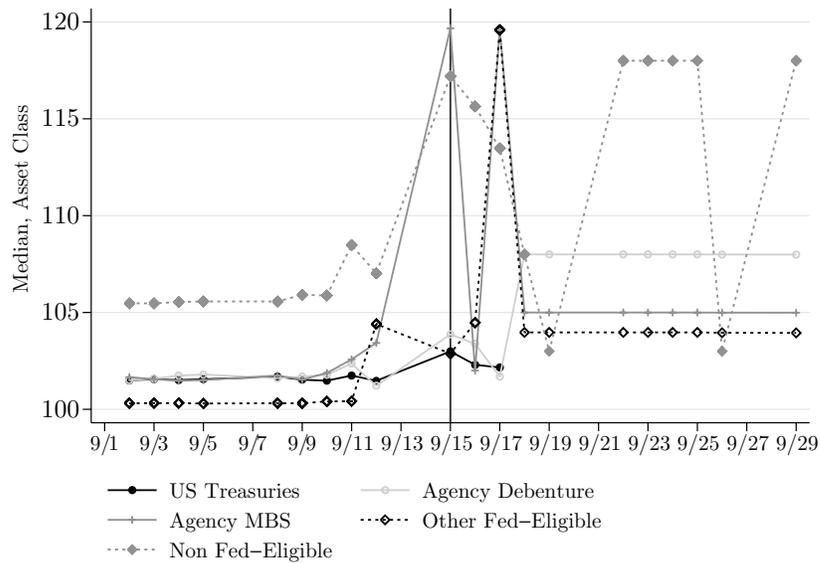
³⁷The increase in haircuts for Lehman is due, in part, to its reliance on the PDCF in the week following the bankruptcy of the holding company.

Figure 23: Median Haircut Rates Around Lehman Bankruptcy



Note: Includes only the most active dealers (those with more than 125 observations at a dealer-asset class level over this period).

Figure 24: Haircuts for Lehman Brothers by Collateral Type



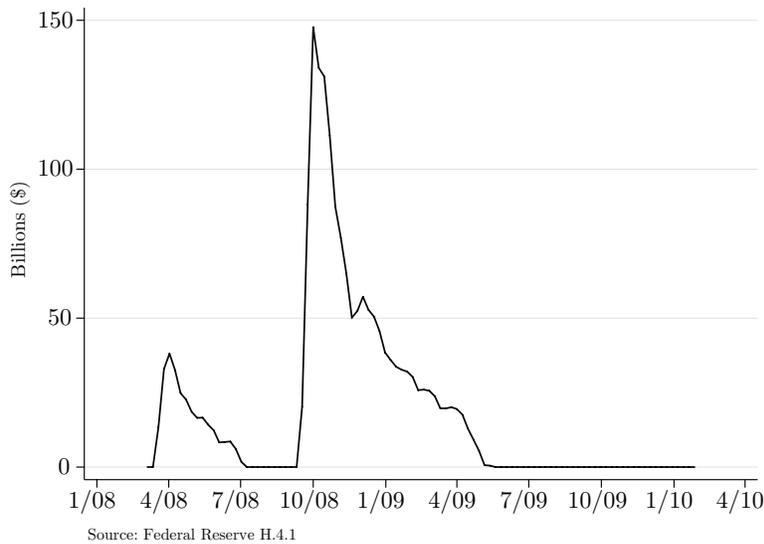
the Lehman Brothers bankruptcy. Figure 25 plots the weekly average of primary and broker-dealer credit on the Fed's balance sheet. The large spikes follow JPMorgan's acquisition of Bear Stearns and LBHI's bankruptcy filing. Adrian, Burke, and McAndrews (2009) note that "usage exploded following the Fed's move to expand PDCF-eligible collateral on September 14 and the bankruptcy of Lehman Brothers Holdings on September 15." The lack of usage of the PDCF during the week before Lehman's bankruptcy could be due to the fear of stigma.³⁸ Valukas (2010) notes that "Paradoxically, while the PDCF was created to mitigate the liquidity flight caused by the loss of confidence in an investment bank, use of the PDCF was seen both within Lehman, and possibly by the broader market, as an event that could trigger a loss of confidence. A report by Lehman Brothers Capital Markets Prime Services captured a common critique of the facility: 'PDCF borrowing has a considerable stigma in spite of the Fed's efforts to cloak access and guarantee anonymity. Instead, primary dealers view the PDCF as a last resort and will exhaust all other financing sources before pledging collateral here. For this reason, borrowing at this program has evaporated since the [Bear Stearns] merger closed.' "

The presence of the PDCF could stabilize the tri-party repo even if it is not used. For example, investors may feel that a particular dealer is unlikely to be troubled unless conditions deteriorate so much that multiple dealers would be in trouble at once. In such conditions, the stigma of going to the PDCF would be reduced, as many dealer may have to rely on it. In this example, the PDCF would provide some insurance in case conditions become worse and which could stabilize the market even if it is not used. The surge in usage of the PDCF following the bankruptcy of Lehman Brothers Holdings on September 15 is consistent with this interpretation (see figure 25).

The PDCF may even have reassured some of Lehman's tri-party repo investors. Recall that while Lehman Brothers Holdings declared bankruptcy on September 15, the broker-dealer did not. The investors that continued to finance the broker-dealer after September 15 did not have to take possession of the collateral backing their repos, in most cases, in part because Lehman

³⁸It is often believed that there is a stigma associated with borrowing at the discount window. See Ennis and Weinberg (2010) for a theory and Armantier, Ghysels, Sarkar, and Shrader (2010) for some empirical evidence.

Figure 25: Weekly Average of Primary Dealer and Broker-Dealer Credit



was able to rely on the PDCF.

5.3 Changes in haircuts in tri-party and other repo markets during the crisis

In this section, we contrast the change in haircuts in the tri-party repo market with the change in haircuts in other bilateral repo markets. As noted above, haircuts moved very little in the tri-party repo market during the crisis. This behavior is very different from the change in haircuts documented in Gorton and Metrick (2009) for an interdealer repo market for low quality collateral. We compare our data of haircuts in the tri-party repo market with haircuts in a market in which dealers are liquidity providers while the collateral providers include hedge funds, real estate investment trusts (REITs), banks, and municipalities. To some extent, the securities that dealers obtain as collateral in the bilateral repo market in which they provide cash can be used by the dealer as collateral in the tri-party repo market to obtain funding.

To make this comparison, we need to match asset classes for the collateral used in both

Table 11: Matching of asset classes

Dealers as cash providers	Dealers as collateral providers (tri-party)
Treasury	US Treasuries and Strips
Agency	Agency Debentures
GSE MBS	Agency MBS
Agency CMO	Agency Remic
High-Grade Corp Debt	Corp Bonds
Alt-A, Prime MBS	Private Label CMO
Subprime	Asset Backed Securities

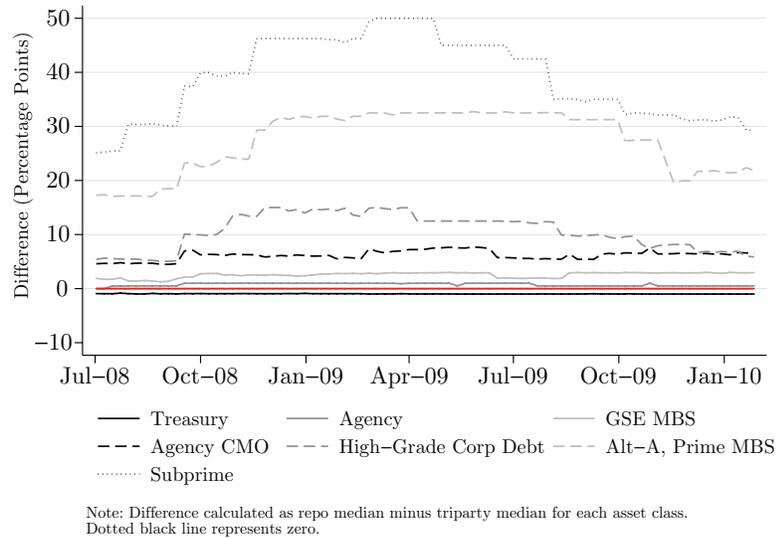
markets as best as possible. Table 11 provides the descriptions of the collateral classes we matched, from most to least liquid collateral.

While the match is not perfect, the collateral classes are roughly similar. Figure 26 plots the difference in median haircut for the two markets, or a haircut ‘spread’. A positive spread indicates that the haircut is lower in tri-party than in the bilateral repo market in which dealers provide cash. When this is the case, a dealer that provides cash to a client against an asset, and uses this same asset in tri-party to obtain cash, would be able to obtain more cash than it lent. Figure 26 shows that the haircut spread is consistently negative for Treasury securities. The spread is positive for all other asset classes and increases as the collateral becomes more illiquid. In addition, the spreads increase during the fall of 2008, peak sometime in the first half of 2009, and are close to their level of July 2008 at the beginning of 2010.

Graph 26 shows that dealers are much more willing to increase haircuts in a bilateral repo transaction than the cash investors of the tri-party repo market. This could be due in part to the dealer’s expertise in asset management and their ability to hold and liquidate assets in a more efficient way.

Several explanations are possible for the large change in haircuts in the bilateral repo market in which dealers provide cash. One possibility is that the riskiness of the dealers’ counterparties, notably hedge funds, increased during the crisis. Hence, the increase in haircut during the crisis would simply reflect the increased risk taken by dealers when providing cash to their

Figure 26: Differences in Haircuts Between Bilateral Repo and Tri-Party Repo



clients through repos. Another possibility is that dealers offering prime brokerage services enjoyed “monopoly rents” at the height of the crisis. Before the fall of Bear Stearns, many hedge funds had only one prime broker. The fall of Bear made these institutions realize the risk of such a situation and many tried to diversify their source of prime brokerage services. However, establishing such relationships can take time and, because of the rush of new demands for services, some prime brokers turned down requests. In this environment, and at the height of the crisis, it is possible that dealers were able to negotiate very favorable terms from their prime brokerage clients when lending cash.

To gauge the effect of the change in haircuts on dealers, we consider how much cash a hypothetical asset portfolio could raise in the tri-party repo market given the level of haircuts before the Lehman bankruptcy and at the peak of level of haircuts. The hypothetical dealer portfolio is taken from Yavorsky and Young (2010), who construct a portfolio based on the Task Force report (Task Force 2010).³⁹ This measure is imperfect since it does not take into

³⁹See table 15 for details of these portfolios.

account the changes in the size and composition of portfolios observed during the crisis. In addition, this measure would miss the effect of investors refusing to further lend to a counterparty (in effect setting the haircuts to infinity). Nevertheless, it gives us a rough measure of the liquidity impact of increased haircuts during the crisis.

The portfolio from Yavorsky and Young (2010) includes \$257 billion in assets, almost 80 percent of which are Fed-eligible assets. Using the average haircuts observed in July and August of 2008, this portfolio would have raised \$250.2 billion in cash in tri-party repo. Using the average haircuts in September through December of 2008, after the Lehman Brothers bankruptcy, this portfolio would have raised \$249.1 billion in cash, about \$1.1 billion less. This funding shortfall represents less than half a percent of the value of the hypothetical portfolio.

While the haircuts in the tri-party repo market did not change very much, the haircuts that dealers were getting from their clients increased considerably during the crisis. Consider a dealer that lends cash to a hedge fund against a security in a bilateral repo and then uses the security to borrow cash in the tri-party repo market. The amount of liquidity that such a dealer would be able to generate from this transaction increased during the crisis. To get a quantitative sense of this effect, we again use the hypothetical portfolio from Yavorsky and Young (2010). For the purpose of this exercise, we assume that the entire portfolio is composed of collateral from bilateral repos through which the dealer lends cash to clients. In addition, we assume that the entire portfolio is then financed in the tri-party repo market. Using haircuts from a survey of hedge funds, for the asset classes we were able to match, our hypothetical dealer raised an additional 1.8% on its portfolio relative to the amount it could have raised prior to the crisis.

6 Conclusions

This paper provides a description of the mechanics of the tri-party repo market and a quantitative account of the activity of that market. Our goal is to document some of the important institutional features of the market and shed some light on the behavior of market participant during the crisis.

An important finding from our study is that the tri-party repo market behaved very differently from other repo markets. For example, Gorton and Metrick (2009) document large increases in haircuts in an interdealer repo market. We also provide evidence of large increases in haircuts for a repo market in which dealers provide cash to their clients. In contrast, haircuts barely moved in the tri-party repo market. This difference in behavior is likely due in part to the nature of the cash investors. Dealers specialize in managing assets and are, thus, more willing to take the risk of having to liquidate securities if a repo counterparty to which they have provided cash fails. Raising haircuts allows dealers to manage this risk. In addition, some dealers that provide prime brokerage services may have been in favorable negotiating positions during the crisis as the demand for these services was particularly strong. In contrast, tri-party repo investors are very reluctant to take possession of collateral and appear to prefer to stop lending to a troubled counterparty, rather than raise haircuts.⁴⁰ This behavior, together with the unwind of repos in tri-party, explain why runs in this market look like traditional bank runs, rather than haircut spirals.

Our data also indicates that the relationship between dealers and investors is very stable. Most dealers can rely on a steady stream of funding from a given set of cash investors. While fluctuations in funding do occur, their size is generally small relative to the size of the portfolios being financed. The stability of these relationship could suggest that investors and dealers try to maintain good reputations. This could play a role in explaining why investors appear to be willing to fund dealers even in situations of market stress.

This observation is related to our last finding: While the tri-party repo market may have been stressed, it appears to have weathered the crisis fairly well. With the notable exception of Lehman, which saw large decrease in the number of its investors and in the quantity of assets financed in the tri-party repo market, most dealers seem to have had reliable access to tri-party repo funding throughout the crisis. Perhaps the biggest reason for the apparent stability of the market is the exceptional policy actions that were taken throughout the crisis, including the

⁴⁰Nevertheless, anecdotal evidence suggest that investors in the tri-party repo market behave differently than unsecured investors. Tri-party repo funding is typically more stable than unsecured funding.

creation of the PDCF. In addition, because tri-party repo funding is very short-term, investors may have been willing to continue to extend funding to dealers in times of stress until the troubles of the dealer become acute. This allows investors to preserve long-term relationships while still being able to pull their funding at the last minute should a dealer become too weak. This observation is also consistent with the idea that runs in this market resemble traditional bank runs.

References

- ADRIAN, T., C. R. BURKE, AND J. J. MCANDREWS (2009): “The Federal Reserve’s Primary Dealer Credit Facility,” *Federal Reserve Bank of New York Current Issues in Economics and Finance*, 15(4).
- ARMANTIER, O., E. GHYSELS, A. SARKAR, AND J. SHRADER (2010): “Stigma in Financial Markets: Evidence from liquidity auctions and discount window borrowing during the crisis,” Federal Reserve Bank of New York, manuscript.
- BRUNNERMEIER, M. K., AND L. H. PEDERSEN (2009): “Market Liquidity and Funding Liquidity,” *Review of Financial Studies*, 22, 2201–2238.
- CHARI, V. V., AND R. JAGANNATHAN (1988): “Banking panics, information, and rational expectations equilibrium,” *Journal of Finance*, 43, 749760.
- CPSS (2010): “Strengthening Repo Clearing and Settlement Arrangements,” Bank for International Settlements.
- CRAPO, D. (2008): “Lehman Brothers Dismantles in Bankruptcy,” *Pratt’s Journal of Bankruptcy Law*, November/December, 702–9.
- DIAMOND, D., AND P. DYBVIK (1983): “Bank runs, deposit insurance, and liquidity,” *Journal of Political Economy*, 91, 401419.
- DUFFIE, D. (2010): *How Big Banks Fail And What to do About It*. Princeton University Press.
- ENNIS, H., AND J. WEINBERG (2010): “Over-the-Counter Loans, Adverse Selection and Stigma in the Interbank Market,” Federal Reserve Bank of Richmond, manuscript.
- FLEMING, M., AND K. GARBADE (2003): “The Repurchase Agreement Refined: GCF Repos[®],” *Federal Reserve Bank of New York Current Issues in Economics and Finance*, 9(6).

- FRBNY (2010): “Tri-Party Repo Infrastructure Reform,” White Paper, Federal Reserve Bank of New York.
- FRIEDMAN, P. (2010): “Testimony of Paul Friedman Before the Financial Crisis Inquiry Commission,” <http://fcic.gov/hearings/pdfs/2010-0505-Friedman.pdf>.
- GARBADE, K. D. (2006): “The Evolution of Repo Contracting Conventions in the 1980s,” *Federal Reserve Bank of New York Economic Policy Review*, 12(1), 27–42.
- GEANAKOPOLOS, J. (2003): “Liquidity, Default, and Crashes, Endogenous Contracts in General Equilibrium,” in *Advances in Economics and Econometrics: Theory and Applications, Eighth World Conference*, ed. by L. P. H. M. Dewatripont, and S. J. Turnovsky, vol. 2, pp. 170 – 205. Cambridge University Press, Cambridge, MA.
- GORTON, G., AND A. METRICK (2009): “Securitized Banking and the Run on Repo,” Yale ICF Working Paper No. 09-14.
- MARTIN, A., D. SKEIE, AND E.-L. VON THADDEN (2010): “Repo runs,” Federal Reserve Bank of New York Staff Report No.444.
- MORRIS, S., AND H. S. SHIN (2009): “Illiquidity Component of Credit Risk,” Princeton University manuscript.
- TASK FORCE (2010): “Task Force on Tri-Party Repo Infrastructure,” Report, Payments Risk Committee.
- TUCKMAN, B. (2010): “Systemic Risk and the Tri-Party Repo Clearing Banks,” CFS Policy Paper.
- VALUKAS, A. (2010): “Report of Anton R. Valukas, Examiner,” Report, In re Lehman Brothers Holdings Inc., et al, Debtors.

YAVORSKY, A., AND R. YOUNG (2010): “Tri-Party Repo Market Remains a Systemic Risk Pending Implementation of Industry Reforms,” Special Comment, Moody’s Investor Services.

ZUBROW, B. (2010): “Written Statement of Barry Zubrow Before the Financial Crisis Inquiry Commission,” <http://www.fcic.gov/hearings/pdfs/2010-0901-Zubrow.pdf>.

Appendix

A TriParty Participants

Table 12: Dealers and Investors in Tri-Party Repo

Alphabetical Listing of Dealers from July 2009 to January 2010			
1	ABN Amro	14	Goldman Sachs
2	BNP Paribas	15	Greenwich
3	Bank of America	16	HSBC
4	Barclays	17	ING
5	CIBC	18	JPMC
6	Cantor Fitzgerald	19	Man Securities
7	Citadel Group	20	Merrill Lynch
8	Citigroup	21	Merrill Lynch (BofA)
9	Credit Suisse	22	Mizuho Bank
10	Daiwa	23	Morgan Stanley
11	Deutsche Bank	24	Raymond James
12	Dresdner	25	UBS
13	G. X. Clarke	26	Wachovia (Wells Fargo)

Alphabetical Listing of Top 25 Investors from July 2009 to January 2010			
1	AIM	14	JPMC
2	BNYM	15	Japan Ministry of Finance
3	Bank of America	16	Merrill Lynch
4	Barclays	17	Morgan Stanley
5	CME	18	Northern Trust
6	Deutsche Bank	19	Schwab
7	Fannie Mae	20	Securities Lending Asset Management
8	Federated	21	State Street
9	Fidelity	22	UBS
10	Freddie Mac	23	US Bank
11	General Collateral Financing	24	Wellington Management
12	Goldman Sachs	25	Wells Capital Management
13	HSBC		

B Tri-party collateral

These details on the collateral accepted in tri-party repo are drawn from a separate source of data on tri-party contracts than that described in section 3.

Table 13: Examples of collateral used in tri-party repo

1	U.S. Treasuries	29	FARMER MAC
2	Treasury STRIPS*	30	Cash Equivalent
3	I&P STRIPS*	31	GNMA Pass Through
4	Private Label Treasury	32	GNMA REMICS
5	Private Label Pass Through	33	FNMA PASS
6	Private Label CMO	34	FNMA REMICS
7	FNMA	35	FHLMC PASS
8	GNMA	36	FHLMC REMIC
9	FmHA	37	1 to 4 Family
10	FHLB	38	Multi Family
11	FHLMC	39	Servicing Advances
12	FICO	40	Commercial Paper**
13	FFCB	41	Commercial Mortgages
14	FCFCA	42	Manufactured Housing
15	SLMA	43	Consumer Auto Loans
16	Resolution Funding Corp	44	Consumer Receivables
17	Other GSEs and Government Agencies	45	Residential Mortgages
18	World Bank	46	Asset Backed Securities**
19	International Institutions/Supranationals	47	Municipal Securities**
20	Foreign Government	48	Corporate Bonds**
21	Trust Receipts	49	Collateralized Mortgage Obligations
22	Bankers Acceptance**	50	Agency Mortgage Backed
23	Mortgage Backed Securities**	51	Convertible Bonds
24	MBS Strips	52	Medium Term Notes**
25	MBS Fixed*	53	Certificates of Deposit**
26	MBS Adjustable*	54	Auction Rate Notes
27	Federal Farm Credit System	55	Debentures*
28	Tennessee Valley Authority	56	Floating Debentures

Note: US Treasuries are sometimes divided into bills, notes, and bonds. * denotes the collateral is sometimes separated by maturity, ** denotes the collateral is sometimes separated by rating.

C A brief overview of repo contracts

In this section, we define what is a repo, or repurchase agreement. We describe the key variables of a repo and highlight differences between repos and collateralized loans.

A repurchase agreement, or repo, is a sale of securities coupled with an agreement to repurchase the securities at a specified price at a later date (Garbade 2006). One party, which we call the cash investor, has cash available that it wants to invest. The other party, which we call the collateral provider, would like to borrow cash and has assets that can be pledged as collateral. The difference between the price at which the securities are sold, and the price at which they are repurchased, can be thought of as the interest rate on a loan. In that respect, a repo is similar to a collateralized loan.

However, a repo is treated differently from a collateralized loan in a bankruptcy. Indeed, a collateralized loan is subject to the automatic stay of bankruptcy, which limits the ability of the lender to sell the collateral quickly. Repos are securities contract and, as such, benefit from a special treatment in case of a bankruptcy. In the tri-party repo market, the main collateral providers are broker-dealers, which are members of the securities investor protection corporation (SIPC). SIPC was created to help investors with assets in the hands of bankrupt and otherwise financially troubled brokerage firms recover their cash, stock and other securities. SIPC plays some of the roles that the FDIC plays for banks, but has a narrower focus and, in particular, provides only limited insurance to investors in SIPC members for some sorts of losses. In the event of the bankruptcy of a SIPC member, SIPC can ask the court for a stay that would extend to close-outs of repos. In other words, SIPC can ask for repos to be subject to the stay of bankruptcy. SIPC routinely asks for a broad stay, but has issued several letters in which it has committed to include in the requested order limited carve-outs for various securities transactions, including repos. Hence, in practice, repos would likely not be subject to the stay of bankruptcy. This special protection afforded to repos protects the cash investor who can quickly recover at least part of the amount of cash it is owed by selling the collateral.

A repo is also different from a straight sale and repurchase in that it allows collateral sub-

stitution. This can be valuable to the collateral provider. For example, consider an institution holding two different securities that could be sold or pledged as collateral in a repo transaction. The institution may also expect that it will need one of the securities for some other purpose in the near future, but it does not know which. If this institution engages in a repo with a counterparty that is willing to accept both securities as collateral, then it can have access to the security it needs by substituting collateral, if necessary. In contrast, if the institution engaged in a sale, with the idea of buying back the security later, it is taking the risk of having to buy the security back sooner than expected, which can be cumbersome and costly.

The value of the securities provided as collateral in a repo is typically different from the amount of cash that the collateral provider receives. The difference between the two amounts is called a “haircut” or margin. In principle either the cash or the collateral provider may have to post margin. For example, a dealer that tries to obtain a very specific security may have to provide cash in excess of the value of the security. In the tri-party repo market the collateral is typically not specific and the collateral provider must pledge securities with a value greater than the cash it receives. In either case, the haircut protects one party to the trade from potential changes in the market value of the collateral in case of default of the other party. In the examples above, when the cash investor posts the margin, the collateral provider is protected against the risk that the value of the security is has provided as collateral increases, making it more costly to acquire the security if the cash investor defaults. When the collateral provider posts the margin, the cash investor is protected against the risk that the value of the security it holds as collateral decreases.

D Financing with a “first-come-first-serve” constraint: bilateral repos

For comparison, it is interesting to consider the case of a bilateral repo market. Because the repos are bilateral, there is a “first-come-first-serve” constraint for the investors. Assume that

Table 14: Payoffs when there is an unwind

Other investors \Rightarrow	0	1	2
Invest	F	S	S
Not invest	$\frac{1}{3}O + \frac{2}{3}F$	$\frac{1}{2}O + \frac{1}{2}F$	O

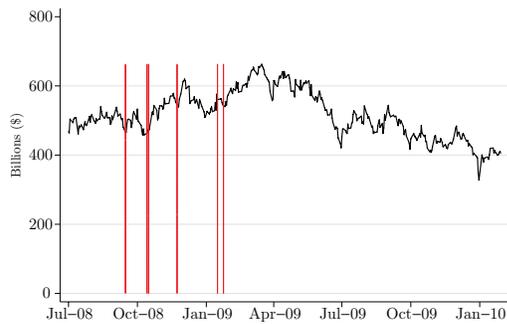
investors form a “line” and that the investors’ place in the line is uniformly distributed. Each investor announces to the dealer whether she wants to reinvest. Other investors do not observe what each investor announces to the dealer. The dealer defaults if two investors choose not to reinvest. Assume that the first such investor is able to get her cash back, but not the second. Table 14 provides the payoffs in the case of bilateral repos.

In this case, as in the case of the tri-party repo market with unwind, coordination failures are possible. A limitation of this simple model in the case of bilateral repos is that it assumes that investors either invest a fixed amount or don’t invest at all. One of the main points of this paper is that this appears to be a reasonable approximation in the case of the tri-party repo market. It may not be a reasonable approximation in the case of bilateral repos, since this market appears to behave very differently.

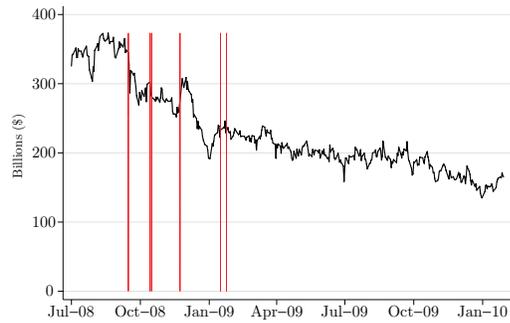
E More Tables and Graphs

Figures 27 to 32 plot the times-series of collateral posted by asset class. These graphs complement Figure 6.

Figure 27: Treasuries: Time Series of Value. Figure 28: Agency debentures: Time Series of Value.

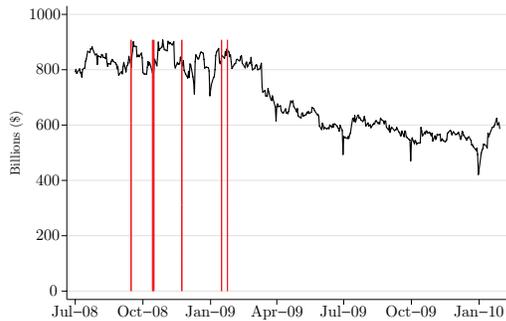


Note: July 17, 2008 excluded because no data was available for BNYM on that date.
 Red lines correspond to important market events. From left to right: 9/15/08 (Lehman),
 10/14/08 (9 banks receive aid), 10/16/08 (UBS), 11/23/08 (Citi), 1/16/09 (B of A), 1/24/09 (Citi).



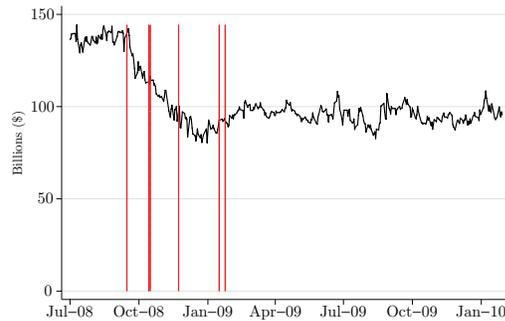
Note: July 17, 2008 excluded because no data was available for BNYM on that date.
 Red lines correspond to important market events. From left to right: 9/15/08 (Lehman),
 10/14/08 (9 banks receive aid), 10/16/08 (UBS), 11/23/08 (Citi), 1/16/09 (B of A), 1/24/09 (Citi).

Figure 29: Agency MBS: Time Series of Value.



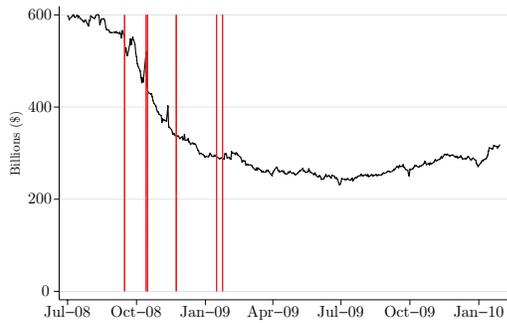
Note: July 17, 2008 excluded because no data was available for BNYM on that date.
 Red lines correspond to important market events. From left to right: 9/15/08 (Lehman),
 10/14/08 (9 banks receive aid), 10/16/08 (UBS), 11/23/08 (Citi), 1/16/09 (B of A), 1/24/09 (Citi).

Figure 30: Other Fed-Eligible: Time Series of Value.

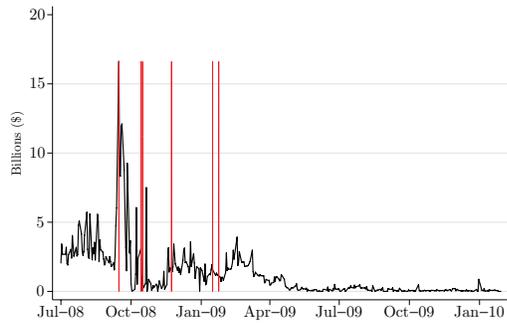


Note: July 17, 2008 excluded because no data was available for BNYM on that date.
 Red lines correspond to important market events. From left to right: 9/15/08 (Lehman),
 10/14/08 (9 banks receive aid), 10/16/08 (UBS), 11/23/08 (Citi), 1/16/09 (B of A), 1/24/09 (Citi).

Figure 31: Non Fed-Eligible: Time Series of Figure 32: Cash as Collateral: Time Series of Value.



Note: July 17, 2008 excluded because no data was available for BNYM on that date.
 Red lines correspond to important market events. From left to right: 9/15/08 (Lehman),
 10/14/08 (9 banks receive aid), 10/16/08 (UBS), 11/23/08 (Citi), 1/16/09 (B of A), 1/24/09 (Citi).



Note: July 17, 2008 excluded because no data was available for BNYM on that date.
 Red lines correspond to important market events. From left to right: 9/15/08 (Lehman),
 10/14/08 (9 banks receive aid), 10/16/08 (UBS), 11/23/08 (Citi), 1/16/09 (B of A), 1/24/09 (Citi).

Figure 33: Changes in Haircuts versus Percent Changes in Volumes

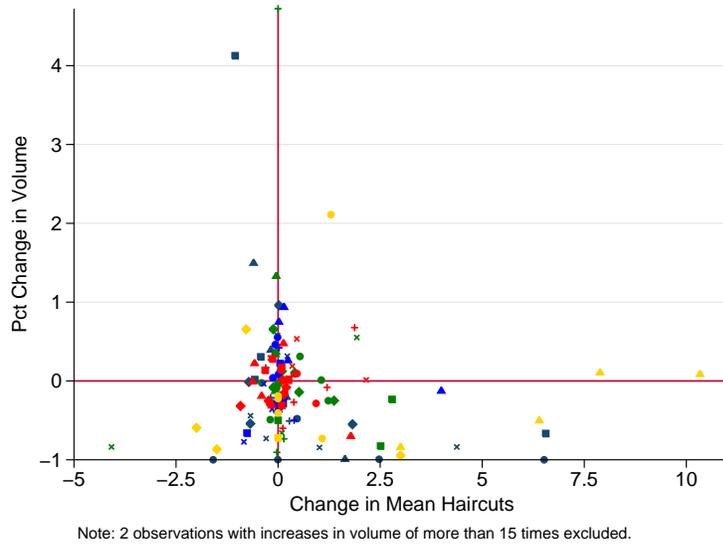


Figure 33 plots the change in haircuts (x-axis) against the percentage change in volume two months before and after the Lehman Brothers episode, excluding the week before and after Lehman declared bankruptcy. Each dealer is denoted by a separate symbol, and each point represents a dealer-asset class combination. The plot indicates that there is no clear-cut relationship between changes in haircuts and changes in volumes. There is heterogeneity across dealers and even across asset classes for an individual dealer. As previously noted, this could be due to varying outside options for different dealers with different asset classes.

Table 15: Shortfall Analysis for Moody's Portfolio with Median Tri-Party Haircut Changes

Asset Class	Market Value	Haircuts			Available Cash			Difference
		Normal	Crisis	Normal Cash	Crisis Cash	Difference		
Agency MBS	\$92	102.2416	102.4583	\$89.94	\$89.74	-\$0.20		
US Treasuries	\$71	101.8382	101.9714	\$69.69	\$69.60	-\$0.09		
Agency Debentures	\$21	102.0028	101.9812	\$20.58	\$20.58	\$0.00		
Agency CMOs	\$18	102.513	102.7139	\$17.55	\$17.51	-\$0.04		
Corporate Bonds - IG	\$11	104.5517	105.7473	\$10.50	\$10.37	-\$0.13		
Equities	\$15	104.9039	105.8423	\$14.26	\$14.12	-\$0.14		
ABS	\$8	104.717	107.016	\$7.62	\$7.44	-\$0.18		
Corporate Bonds - SG	\$7	104.5517	105.7473	\$6.68	\$6.60	-\$0.08		
Money Markets	\$7	102.9935	104.107	\$6.79	\$6.71	-\$0.08		
Private Label CMO - SG	\$4	105.9089	106.3186	\$3.76	\$3.75	-\$0.02		
Private Label CMO - IG	\$3	105.9089	106.3186	\$2.82	\$2.81	-\$0.01		
Totals	\$257.00			\$250.20	\$249.23	-\$0.97		
Shortfall as % of portfolio	0.38%							