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Key Mechanics of the U.S. Tri-Party Repo Market

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Key Mechanics of the U.S. Tri-Party Repo Market

- The 2007-09 financial crisis exposed weaknesses in the design of the U.S. tri-party repo market that could rapidly elevate and propagate systemic risk.
- A study of the market identifies the collateral allocation and unwind processes as two key mechanics contributing to the market's fragility and delaying reforms.
- The problems stem from the considerable intervention by dealers to allocate collateral and their reliance on intraday financing to unwind, or settle, expiring repos.
- Streamlining the collateral allocation process and eliminating the time gap associated with the unwinding of repos could reduce market fragility and financial system risk.

1. Introduction

During the financial crisis of 2007-09, particularly around the time of the Bear Stearns and Lehman Brothers failures, it became apparent that weaknesses existed in the design of the U.S. tri-party repo market, used by major broker-dealers to finance their inventories of securities. These design weaknesses had the potential to rapidly elevate and propagate systemic risk.

Following the crisis, an industry-led effort sponsored by the Federal Reserve Bank of New York was undertaken to improve the tri-party repo market's infrastructure, with the main goal of lowering systemic risk. This article describes some key mechanics of the market—in particular, the collateral allocation process and the “unwind” process—that have contributed to the market's fragility and delayed the reforms.

A repurchase agreement, or “repo,” is effectively a collateralized loan. A well-functioning tri-party repo market depends on the ability to efficiently allocate a dealer's securities—the collateral in the transaction—to the various repos that finance those securities. In the United States, collateral allocation currently involves considerable intervention by dealers, which slows the entire process. Collateral allocation is also complicated by the need for coordination between the Fixed Income Clearing Corporation (FICC), which clears some interdealer repos, and the clearing bank, which facilitates the settlement of tri-party repos. The

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length of time necessary to allocate collateral in the tri-party repo market has been a significant obstacle to market reform.

Another impediment to reform is the unwind process, the settlement of expiring repos that occurs before new repos can be settled. The unwind creates a need for intraday funding to tide dealers over in the period between when they return cash to investors and when they get new cash from the settlement of new repos. In the tri-party repo market, this intraday financing is provided by the clearing banks. The dealers' reliance on intraday credit is one of the three weaknesses of the market highlighted in a Federal Reserve Bank of New York white paper on infrastructure reform. Such reliance creates potentially perverse dynamics that increase market fragility and financial system risk.

The next section offers a brief overview of the U.S. repo market and some of its important segments. In Section 3, we describe the market in more detail and summarize the concerns surrounding it. Section 4 reviews the mechanics of tri-party repo transactions; Section 5 concludes.

2. The U.S. Repo Market

A repo is the sale of a security, or a portfolio of securities, combined with an agreement to repurchase the security or portfolio on a specified future date at a prearranged price. Aside from some legal distinctions concerning bankruptcy treatment,¹ a repo is similar to a collateralized loan. Exhibit 1 shows a basic repo transaction. For the opening leg of the repo, an institution with cash to invest, the cash provider, purchases securities from an institution looking to borrow cash, the collateral provider.

The market value of the securities purchased typically exceeds the value of the cash. The difference is called the "haircut." For example, if a cash loan of \$95 is backed by collateral that has a market value of \$100, then the haircut is 5 percent. For the closing leg of the repo, which occurs at the term of the repo, the collateral provider repurchases the securities for \$95 plus an amount corresponding to the interest rate on the transaction.

In most segments of the U.S. repo market, at least one of the counterparties is a securities dealer.² Dealers use the repo market to finance their inventories of securities, among other purposes. In some cases, the collateral provider is a client of the dealer that wants to borrow cash. On these repos, the dealer is the cash provider. Repos involve a variety of other cash providers, including money market funds (MMFs), asset managers, securities lending agents, and investors looking to obtain specific securities as collateral in order to hedge or

¹ See Duffie and Skeel (2012).

² The terms "dealer" and "securities dealer" are used interchangeably.

Exhibit 1

A Typical Repo Transaction

Opening leg



Closing leg



speculate based on changes in the market values of those securities.

We now describe different segments of the U.S. repo market in more detail.

2.1 The Bilateral Repo Market

When the repo market was first developed, all transactions were bilateral. In the bilateral market, a repo is typically settled when the collateral provider receives the cash and delivers the securities to the cash provider. The transfer is usually simultaneous, so this type of repo is sometimes called "delivery versus payment," or DvP. For example, for a repo collateralized by Treasury securities, the collateral provider could instruct its custodian bank to deliver the appropriate securities to the cash provider's custodian bank through the Fedwire Securities Service.³

Bilateral repos have some operational complexities. They typically require the cash provider to be able to 1) keep track of the securities collateral it receives, 2) make sure that this collateral is adequate and valued correctly, and 3) ensure that the proper margin has been applied. All of this requires significant operational expertise and systems, especially for large investors that do many repos with a variety of counterparties.

To avoid this complicated process, a collateral provider could offer to hold the securities, but segregate them for the benefit of the cash providers. Such repos are called "hold in custody," but they are no longer popular for two reasons. First, the cash investor may find it difficult to obtain its securities should the collateral provider default. Second, these repos involve the potential for fraud. These complexities are alleviated in the tri-party repo market, which we describe later.

The bilateral repo market has two main segments, one in which dealers borrow cash and another in which dealers lend cash. We describe each in more detail.

³ The Fedwire Securities Service is operated by the Federal Reserve System.

The Bilateral Market in Which Dealers Borrow Cash

Some DvP repos are collateralized by a security that is in particular demand. For example, the cash provider might want the security for delivery against a short sale or to cure a delivery failure. These sought-after securities are typically called “special,” and often include the most recently issued (“on-the-run”) Treasury securities. Investors are often willing to accept a lower interest rate on a repo collateralized by a special security.

Repos involving specific securities are typically bilateral. The cash providers in this segment of the market are usually hedge funds and dealers. When both counterparties are dealers, the repo does not provide net funding to the dealer community in the aggregate, but redistributes the available cash and specific securities among dealers. Copeland, Martin, and Walker (2010) estimate the size of this segment of the repo market at almost \$1 trillion as of May 2012. Gorton and Metrick (2012) provide information about haircuts in the interdealer bilateral market.

The Bilateral Market in Which Dealers Lend Cash

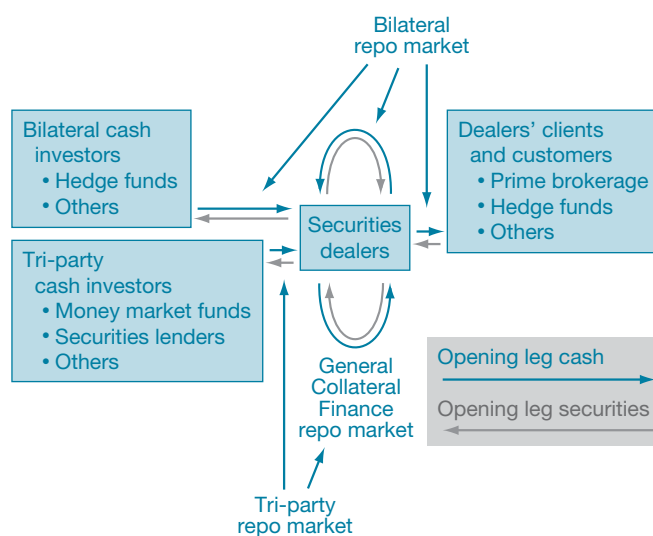
In another segment of the bilateral market, dealers finance their clients’ assets or lend cash to each other. Financing a client’s assets is particularly convenient if the dealer holds these same assets in custody, because the dealer can simply assert a lien on the securities that collateralize the repo. The securities obtained by the dealer in this process can then be rehypothecated in other repo transactions, if the collateral provider allows it. Copeland, Martin, and Walker (2010) estimate the size of this segment of the repo market at almost \$2 trillion as of May 2012.⁴ They also provide information about haircuts that dealers require for financing their clients’ assets.

2.2 The Tri-Party Repo Market

In the tri-party repo market, a third party, called a clearing bank, facilitates repo settlement. In the United States, two clearing banks handle tri-party repos: Bank of New York Mellon (BNYM) and JP Morgan Chase (JPMC). These clearing banks settle repo transactions on their own balance sheets. Maintaining cash and securities accounts for dealers and cash providers, the clearing banks settle the opening leg of a tri-party repo by transferring securities from the dealer’s securities

⁴ Note that adding up the size of the two segments of the bilateral repo market would double count interdealer activity, since one dealer is borrowing and another is lending. The available data do not allow us to separate that activity.

EXHIBIT 2
The U.S. Repo Market



account to the cash investor’s securities account, and by transferring cash from the investor’s cash account to the dealer’s cash account. Movements in the opposite direction occur on the closing leg of the repo (Exhibit 2).⁵

In addition to offering settlement and custodial services, clearing banks provide collateral management services, such as daily revaluation of assets, daily remargining of collateral, and allocation of the borrower’s collateral to its lenders in accordance with the lenders’ eligibility and risk management constraints. As explained by Garbade (2006), clearing banks also ensure that the collateral will be available to cash providers if a dealer defaults.

The tri-party repo market has two main segments, described in more detail below.

Tri-Party Repos Funded by Nondealers

Cash providers in this segment of the market are primarily MMFs, securities lenders, and other institutional cash providers, such as mutual funds, corporate treasurers, and state and local government treasurers. These investors seek interest income at short maturities. For some investors, overnight repos serve as a secured alternative to bank deposits. Together, MMFs and securities lenders account for over half of tri-party repo lending (Copeland, Martin, and Walker 2010).

⁵ The mechanics of tri-party repo transactions are described in Section 4.

Table 1
 Composition and Concentration of Tri-Party Repo Collateral
 June 11, 2012

Asset Group	Collateral Value (Billions of Dollars)	Share of Total (Percent)	Concentration by Top Three Dealers (Percent)
Fedwire-eligible collateral			
U.S. Treasuries, excluding Strips	578.24	32.1	30.2
U.S. Treasury Strips	47.17	2.6	49.6
Agency debentures and strips	106.99	5.9	36.6
Agency mortgage-backed securities	680.82	37.8	30.9
Agency collateralized mortgage obligations (CMOs)	126.04	7.0	43.9
Non-Fedwire-eligible collateral			
Asset-backed securities, investment- and noninvestment-grade	35.33	2.0	45.5
CMO private-label, investment- and noninvestment-grade	34.13	1.9	47.2
Corporates, investment- and noninvestment-grade	63.81	3.5	31.6
Equities	80.85	4.5	39.8
Money market instruments	25.17	1.4	60.8
Other	22.01	1.2	
Total	1,628.04		

Source: Tri-Party Repo Infrastructure Reform Task Force (http://www.newyorkfed.org/tripartyrepo/margin_data.html).

Notes: "Other" includes collateralized debt obligations, international securities, municipality debt, and whole loans. The underlying data include a total of 7,104 deals and 10,282 collateral allocations.

Dealers use the tri-party repo market mainly to obtain large-scale, short-term financing for their securities inventories at a low cost. They typically use only one of the two clearing banks to settle their tri-party repos. Large cash providers maintain accounts at both clearing banks in order to transact with dealers at each of them.

The tri-party repo market is a general collateral (GC) market, meaning that an investor may care about the class of collateral it receives but not about the specific securities.⁶ The market is the largest source of secured funding for U.S. dealers. As shown in Table 1, U.S. Treasury securities and various U.S. government agency obligations (mortgage-backed securities [MBS], debentures, and collateralized mortgage obligations) accounted for approximately 85 percent of U.S. tri-party repo collateral in June 2012. The total amount of financing provided in the U.S. tri-party repo market then—about \$1.8 trillion—was down from a precrisis peak of about \$2.8 trillion.

⁶ This is in contrast to the market for special securities. Tri-party repo cash providers typically are not interested in specific securities. In addition, as described in Section 4, the clearing bank's collateral allocation process does not facilitate the allocation of specific securities to a repo. For these reasons, special securities are not financed in the tri-party repo market.

The GCF Repo Market

The GCF (General Collateral Finance) repo market is a blind-brokered interdealer market, meaning that dealers involved in the transactions do not know each other's identity. GCF trades are arranged by interdealer brokers that preserve the participant's anonymity. Only securities that settle on the Fedwire Securities Service can serve as collateral for a GCF repo transaction. GCF repo trades are settled on the books of the clearing bank using the tri-party repo infrastructure and thus are an integral part of tri-party repo settlement.⁷

The GCF market has several functions for dealers. Some use the market for a substantial share of their inventory financing, on an ongoing basis. Dealers can also use GCF repos to fine-tune their financing at the end of the day, lending cash if they have secured more financing than they need or borrowing cash if they are short. Dealers also use GCF repos for collateral upgrades, borrowing cash against agencies' MBS collateral and reinvesting the cash against Treasury securities. They may choose to do this because it is easier to finance Treasury securities than agency MBS outside of the GCF market or because they need to make a pledge to a central counterparty that accepts only Treasuries as collateral. (The data in Table 1 do not include the GCF market

⁷ Fleming and Garbade (2003) provide an overview of the GCF market.

Table 2
 Distribution of Investor Haircuts on Tri-Party Repos
 June 11, 2012

Asset Group	Cash Investor Margin Levels		
	10th Percentile	Median	90th Percentile
Fedwire-eligible collateral			
U.S. Treasuries, excluding Strips	2.0	2.0	2.0
U.S. Treasury Strips	2.0	2.0	2.0
Agency debentures and Strips	2.0	2.0	5.0
Agency mortgage-backed securities	2.0	2.0	3.0
Agency collateralized mortgage obligations (CMOs)	2.0	3.0	5.0
Non-Fedwire-eligible collateral			
Asset-backed securities, investment- and noninvestment-grade	3.0	7.0	15.0
CMO private-label, investment- and noninvestment-grade	2.0	8.0	15.0
Corporates, investment- and noninvestment-grade	2.0	5.0	15.0
Equities	5.0	8.0	15.0
Money market instruments	2.0	5.0	5.0

Source: Tri-Party Repo Infrastructure Reform Task Force (http://www.newyorkfed.org/tripartyrepo/margin_data.html).

Notes: Figures are percentages. The underlying data, which are common to those underlying Table 1, include a total of 7,104 deals and 10,282 collateral allocations.

because the market does not provide net financing to the dealer community in the aggregate. Instead, the market allows dealers to redistribute cash among themselves.⁸)

3. Tri-Party Repo Transactions

Because a repo is effectively a collateralized loan, the key terms are the same for both: borrower and lender, maturity date, cash loan amount, interest rate,⁹ collateral eligibility, margin schedules, and the treatment of the contract in the event of either party's failure. For tri-party repos, the time to maturity, or tenor, is commonly one day. Many such "overnight" repos, however, are "rolled" for a number of successive days. A "term" repo has a tenor of more than one day.

To establish a tri-party trading relationship, a cash provider and a cash borrower execute a master repo agreement (MRA) that stipulates the key elements of their prospective tri-party

⁸ The Federal Reserve Bank of New York and the Depository Trust and Clearing Corporation provide data on the GCF market. See http://www.newyorkfed.org/tripartyrepo/margin_data.html and <http://www.dtcc.com/products/fi/gcfindex/>, respectively.

⁹ The interest rate is quoted on a standard money market basis. For example, in U.S. dollars, the "actual/360" money market convention implies that a loan of \$100 for three days at an interest rate of 2 percent is repaid with interest of $\$100 \times 0.02 \times 3/360$.

repos, such as how a repo may be terminated and how margins will be maintained. The MRA also outlines the conditions under which the collateral backing the repo can be replaced by other collateral. The borrower and lender each have, in addition, clearing agreements with a tri-party clearing bank, either JPMC or BNYM. Like repos, clearing agreements are exempt from bankruptcy stays, which allows these agreements to terminate in the event of bankruptcy, giving the collateral holder the immediate right to use or dispose of the collateral.¹⁰ Finally, a custodial undertaking agreement (CUA), executed by the two MRA signatories as well as the clearing bank, establishes the clearing bank as the tri-party agent for this lender-borrower relationship and documents the lender's collateral eligibility criteria.¹¹

An annex to the custodial agreement stipulates the haircuts applicable to each class of collateral that the investor will accept. Hence, the haircut is not negotiated on a trade-by-trade basis. The haircut may depend on a number of factors, including the historical price volatility for the asset type, the loan term, and the identity of the dealer.¹²

¹⁰ Clearing agreements are "securities contracts," exempt from automatic stays, preferences, and other bankruptcy rules. See Duffie and Skeel (2012).

¹¹ The annexes of the CUA contain schedules that define the eligible collateral for a particular type of repo as well as the haircut for each collateral type. Section 4.2 provides more detail.

¹² Copeland, Martin, and Walker (2010) explain that haircuts depend on the dealer.

Table 2 provides summary statistics for the cross-sectional distribution of overnight haircuts set in the U.S. tri-party repo market in May 2011.¹³ The median haircut applied to U.S. Treasuries was 2 percent, while the median haircuts on corporate bonds and equities were 5 percent and 8 percent, respectively, reflecting their generally higher volatility or lower liquidity compared with Treasuries. The annex to the custodial agreement may also specify concentration limits, such as no more than 40 percent agency securities and no more than 25 percent corporate bonds.

Once these various contracts are in place, dealers can engage in tri-party repo transactions with cash providers. They negotiate the interest rate, the type of eligible collateral, the tenor, and the size of each repo. Typically, a dealer's repo traders call investors in the morning to arrange new repos. Industry participants report that 80 to 90 percent of tri-party repo funding is arranged before 10:00 a.m. In some cases, such as for a large fund complex, a deal is negotiated in the morning but the allocation to specific funds within the complex is not indicated until later in the day. Some trades, however, are arranged later in the day. For example, MMFs that accept redemptions from their investors until late in the afternoon would not know the amount of cash they will invest until that time.

Dealers and investors have incentives to maintain the quality of their relationships, so they try to accommodate each other's needs when possible. This may occur if an investor experiences some unexpected changes in available cash. For example, a dealer may allow some classes of investors, such as MMFs, to deviate by up to 10 percent from the originally agreed-upon deal size. If a dealer lacks sufficient amounts of eligible securities, it will typically post cash collateral, which is generally acceptable. In this case, however, the dealer pays interest on this component of the repo without borrowing any net amount of cash. Each day, a clearing bank settles the opening legs of new repos as well as the closing legs of any repos to be settled on that day, acting as agent for both the borrower and lender. As we explain in Section 4, the dealer and its clearing bank have some discretion with regard to the specific packages of collateral to allocate to each repo deal, subject to meeting the deal's collateral requirements. The clearing bank is heavily involved in the collateral allocation process and in the transfer of cash and securities between the accounts of the borrower and lender.

¹³ Monthly data back to May 2010 are available at http://www.newyorkfed.org/tripartyrepo/margin_data.html.

3.1 The Role of the Clearing Banks as Intraday Investors

The financial strains experienced by several dealers, including Bear Stearns and Lehman Brothers, during the financial crisis of 2007-09 highlighted the fact that the two tri-party clearing banks are not only agents, but also the largest creditors in the tri-party repo market on each business day. This daytime exposure is associated with the unwind of repos, a process by which the clearing banks send cash back to investors and collateral back to dealers, regardless of whether a repo is expiring.¹⁴

Between the time of the unwind and the time at which new trades are settled near the end of the business day, dealers must finance the securities that serve as repo collateral. During this transition period, the clearing banks provide financing to dealers, collateralized by the dealers' securities.¹⁵ This provision of intraday credit creates multiple risks.

The exposure of a clearing bank to a single dealer can routinely exceed \$100 billion (Federal Reserve Bank of New York 2010). In the event that a dealer fails, its clearing bank could, in an unexpected situation, discover that the market

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value of the collateral provided by the dealer is insufficient to cover the amount owed to the clearing bank. The stability of the clearing bank could also be threatened if it decides instead to hold the collateral on its own balance sheet, thereby increasing its leverage.

The vulnerability of a clearing bank to a troubled dealer is intensified by "wrong-way" risk, meaning that, in a crisis situation, the failure of a dealer may be correlated with a

¹⁴ The unwind process is described in more detail in Section 4.

¹⁵ Clearing banks may apply a haircut to the intraday repo financing of dealer inventories. United States Bankruptcy Court (2010, pp. 1095-1102) documents that one clearing bank increased haircuts abruptly during the crisis to a level that, in some cases, exceeded those charged by cash providers.

sudden reduction in the market value of some securities that collateralize the dealer's tri-party repos. Moreover, an attempt by a clearing bank to lower its exposure to a failed dealer through a sudden "fire sale" of the collateral could itself reduce the value of that collateral, thus exacerbating the losses to the clearing bank and to other market participants that hold positions in the same or similar assets. This danger buttresses the importance of the Primary Dealer Credit Facility (PDCF), introduced by the Federal Reserve Bank of New York during the financial crisis (Adrian, Burke, and McAndrews 2009). The PDCF provided an alternative source of financing for collateral that might otherwise have been liquidated in a fire sale; such a liquidation could have potentially destabilized the markets and eroded the capital of these asset holders.

As explained by Duffie (2010), the exposure of tri-party clearing banks to securities dealers also represents a potential danger to any dealer whose credit quality becomes suspect. A clearing bank refusing to unwind the repos of such a dealer could suddenly and fatally restrict that dealer's ability to finance itself. Section 4 explains how the daily morning "handoff" of dealer exposure from cash providers to the clearing bank creates an incentive for the clearing bank to pull away from granting credit to a dealer in the event of concerns over that dealer's credit quality. In the case of Lehman Brothers, such instances are documented by Anton R. Valukas in his report as bankruptcy examiner (United States Bankruptcy Court 2010) and by the report of the Financial Crisis Inquiry Commission (2011).

Concerns over the failure of a large dealer arise in part from the stress likely to spread to other financial markets, as was the case with the run on MMFs following the failure of Lehman Brothers. This run was triggered when the Reserve Primary Fund announced large losses on its investments in Lehman commercial paper. From September 9 to September 30, 2008, institutional investors withdrew approximately \$450 billion (about one-third of their assets) from "prime" MMFs.¹⁶ Significantly greater redemptions would likely have occurred had the U.S. Treasury not quickly guaranteed the performance of money market funds, an action that it has pledged not to take in the future (McCabe 2010).

4. Key Market Mechanics

Two key processes in the U.S. tri-party repo market contributed to its fragility during the financial crisis of 2007-09 and have delayed the current market reforms. The first is the afternoon collateral allocation process. The redesign of this process has proved more

¹⁶ The data are provided in Duffie (2010).

complicated than expected by the industry task force charged with the reform, and has therefore become a focus. The second is the morning unwind, the process by which clearing banks return cash to lenders' cash accounts and the collateralizing assets to dealers' securities accounts.

4.1 The Afternoon Collateral Allocation Process

In the afternoon, new repo deals must be settled.¹⁷ This process, which occurs on the books of the clearing bank, consists of transfers of cash from the clearing accounts of the investors to those of the dealers, and transfers of securities from the clearing accounts of the dealers to those of the cash providers. The dealer's objective is to allocate its collateral to lenders in a way that is efficient from the viewpoint of financing costs and collateral usage, while meeting each lender's criteria for acceptable portfolios of collateral. This can present a

Two key processes in the U.S. tri-party repo market contributed to its fragility during the financial crisis of 2007-09 and have delayed the current market reforms.

relatively high-dimensional and complex mathematical programming problem because of the number of deals available to each dealer as well as the number and types of constraints on collateral imposed by individual cash providers. The allocation process is the responsibility of the dealer's clearing bank, although in many cases a dealer may become involved. This section provides a general overview of the allocation process in a typical U.S. tri-party repo setting.

The Dealer's Problem

A large dealer might have tri-party repo relationships with, say, twenty or more significant cash providers. Each relationship can involve many different deals on a given day. For example, the tri-party repo relationship between a dealer and an asset manager responsible for a mutual fund complex could involve cash loans to the dealer from each of a number of mutual funds

¹⁷ In addition, following the unwind process, term and rolling repos must also be rewound.

in the complex. Even a particular mutual fund may lend cash to the dealer through more than one tri-party repo deal on a given day. Each deal represents, in effect, a loan of cash for a given term, collateralized by a portfolio of securities meeting requirements that are stipulated in the tri-party agreement negotiated in advance by the cash investor and the dealer. The interest rate on the loan depends on the types of securities identified as eligible collateral.

Each cash investor has a “rule set” governing the portfolio of collateral that is acceptable under its repo agreement. The rule set is a collection of restrictions on the acceptable types of collateral (defined by issuer type, issuer name, security identifier [such as CUSIP], maturity, credit quality, currency, and many other properties) as well as concentration limits across types of securities. A basic rule set simply specifies the acceptable types of collateral and the associated haircuts.

A large dealer might have tri-party repo relationships with, say, twenty or more significant cash providers. Each relationship can involve many different deals on a given day.

Indeed, for U.S. Treasuries, agency debt, and agency MBS, which constitute the majority of the U.S. tri-party repo market, deals are often arranged with a specific security type in mind. The rule set is part of the CUA signed by the cash investor, the collateral provider, and the clearing bank.

Typical rule sets have evolved, becoming more complicated over time, especially for repos that may be backed by equities or non-Fedwire-eligible collateral.¹⁸ For example, a rule set might specify “Only U.S. Treasuries, agency securities, and investment-grade, U.S.-dollar corporate bonds are acceptable. No more than 30 percent of the portfolio may be corporate bonds.” The language of a tri-party repo master agreement is, of course, more precise than this description, which we offer only for illustration.

Timing

In the current market infrastructure, the collateral allocation process takes several hours, extending from about 3:00 p.m. to 6:00 p.m. or, for some dealers, to 6:30 p.m. The lateness of the allocation process is due to a number of factors.

¹⁸ Fedwire-eligible collateral is collateral settled on the Fedwire Securities Service.

Some of a dealer’s Fedwire-eligible securities, primarily U.S. Treasury and agency securities, are not available in its “box,” the set of securities to which it holds title, until the Fedwire Securities Service’s 3:30 p.m. close for interbank transactions. The visibility of their holdings of Fedwire-eligible securities is limited prior to 3:30 p.m., so dealers prefer to begin allocating these securities to tri-party deals no earlier than this time.

Most dealers also trade in the GCF repo market. A dealer may choose—or, depending on its available securities, need—to wait for its GCF trades to settle before completing some of its tri-party repo allocations. Settlement of GCF repos can last until 4:30 p.m. or, on certain days, until 5:00 p.m. The length of this settlement period can lead to significant additional delays in the completion of the tri-party collateral allocation process.

Equities can be allocated to repos from the accounts that dealers hold at the Depository Trust Company (DTC). As with the handoff of GCF repo collateral, the receipt of DTC-eligible collateral may need to occur before some tri-party repo deals can be settled. Currently, DTC-eligible collateral becomes available as late as 4:30 p.m., although dealers may obtain partial delivery before that time if all DTC liens against the collateral have been released.

Although the tri-party collateral allocation process can begin before all DTC-eligible collateral is available and before all GCF repos are settled, it usually cannot be completed until these other steps have themselves been completed. In addition to delays caused by the timing of the handoffs of collateral involving Fedwire, DTC, and the FICC, the collateral allocation process itself takes considerable time because many dealers choose to “manually” intervene in this process, for reasons that will be discussed.

Mechanics of the Allocation Process

The allocation process for each dealer has two basic steps. In the first, the dealer’s allocation decision problem is solved, manually or with the assistance of mathematical programming software. The solution is a set of portfolios of securities, one for each repo. The second step is the transfer of title to these securities out of the dealer’s box and into the collateral accounts that cash providers hold at the clearing bank. This transfer of title is made against transfers of cash from the cash providers’ accounts (at the clearing bank) into the borrowing dealer’s cash account (at the clearing bank).

To facilitate the first step, the clearing banks make their collateral allocation systems available to the dealers. A common algorithm orders the repo deals, typically from least to most

Collateral Allocation Algorithms

For purposes of software input, a cash provider's rule set is converted into a combination of mathematical restrictions. For example, a concentration limit can be specified in terms of a linear inequality constraint of the form

$$C(k, n): b(1, k, n)x(1, n) + b(2, k, n)x(2, n) + \dots + b(m, k, n)x(m, n) \leq c(k, n),$$

where $x(i, n)$ is the market value of security number i allocated to deal n , $b(i, k, n)$ is the contribution of security i to constraint k of deal n , and $c(k, n)$ is the constraint maximum, such as the allowable market value of securities that may be allocated under the k -th constraint of deal n .

For instance, if the cash loan size of deal n is \$100 million and if the k -th constraint on this deal specifies that no more than 30 percent of the collateral (after haircuts) may be investment-grade corporate bonds, and if the associated haircut implies multiplication by a factor of 1.05, then $c(k, n) = \$31.5$ million and $b(i, k) = 1$ if the i -th security in the dealer's "box" is a corporate bond; otherwise, $b(i, k) = 0$.

Constraints that rule out securities of a particular type, such as speculatively rated corporate bonds, can be specified by a constraint of the form " $x(i, n) = 0$ " for any security i of the excluded type.

Rules can be combined via "logical and" and "logical or" operations. For example, a rule set could require:

$$[C(1, n) \text{ AND } C(2, n) \text{ AND } C(3, n)] \\ \text{OR } [C(1, n) \text{ AND } C(4, n)],$$

meaning that the allocation to the n -th deal must meet all of the restrictions $C(1, n)$, $C(2, n)$, and $C(3, n)$ —or, alternatively, can be satisfied by meeting restrictions $C(1, n)$ and $C(4, n)$.

There can also be cross-deal concentration limits associated with groups of deals from the same dealer client. Of course, there are also cross-deal constraints associated with the dealer's total available amounts of each security, which can be specified in the form

$$x(i, 1) + \dots + x(i, N) \leq v(i),$$

where N is the total number of deals to be populated with collateral and $v(i)$ is the total market value of security i in the dealer's "box" available for allocation. Of course, there is also a nonnegativity restriction on $x(i, n)$ for all i and n .

This mathematical description of the problem constraints does not necessarily explain the software or methods actually used by clearing banks; rather, it is used here to illustrate the underlying nature of the problem.

For a given dealer, a simple allocation algorithm could begin by determining preliminary allocations, deal by deal, taking some particular dealer-specified ordering of deals (or "deal sort"), such as "largest deal first." The dealer may also rank the available collateral in the order that it wishes to have the collateral allocated, with the most desired ranked first. Dealers often prefer to conserve their most liquid securities, such as U.S. Treasuries, by first allocating relatively illiquid ones.

For example, a simple algorithm would allocate securities, type by type, with the highest-ranked security allocated first, to deals in the given deal order, until the available quantity of the given type of security is exhausted or until each deal has the maximum amount of that security consistent with its concentration limits. This iterative algorithm is not an explicit optimization, beyond the desired effects of security rankings and deal order.

An explicit optimization algorithm could, for instance, maximize the total quantity of financing from deals that can be collateralized with the available pool of securities. Alternatively, the algorithm could be designed to minimize the dealer's net interest expense for financing the dealer's securities (the "cost of carry") or to minimize the use of margin (that is, other things equal, show preference to deals with lower average haircuts). Various forms of optimization criteria could be tried, allowing the dealer to select the preferred allocation among the resulting outputs.

If an allocation algorithm is unable to populate all of the deals with the initially available pool of dealer collateral, the dealer may then "upgrade" the collateral pool. For example, in order to achieve a feasible allocation, the dealer could upgrade the basket of available securities by adding some U.S. Treasuries, which are typically accepted in most deals. A dealer may even complete a collateral package with cash. The dealer's upgrade schedule can be priority ranked, with the most desired collateral to be allocated ranked first.

If, even with upgrades, the amount and mix of collateral are insufficient to cover all deals, some rationing algorithm must be used, unless the dealer is able to renegotiate some trades. A dealer could have sufficient amounts of financing, but nevertheless fail on some deals because of insufficient collateral. In such a case, the dealer could prioritize specific clients, or give preference to older deals or those that could be collateralized with securities from markets that have already closed.

restrictive in their collateral concentration limits, and ranks the collateral, typically from lowest to highest quality. The repo deals are then allocated collateral, one by one, with assets in rank order. Some dealers, particularly small ones, use this algorithm to allocate their entire tri-party repo books.

Some dealers feel they can achieve a better collateral allocation with a "script," each step of which uses the ranking-based algorithm described above but applied only to a restricted set of deals and a restricted set of collateral. For example, one step could be to allocate a dealer's Treasury

collateral to deals that accept only Treasuries. By using this approach, dealers can better control the allocation process. This method has the benefit of not requiring a CUSIP-level specification of the allocation of securities. (The box provides additional details on collateral allocation algorithms.)

The collateral allocation systems used by the clearing banks do not have filters that are sufficiently granular to meet some cash providers' collateral requirements. For example, some investors may accept residential MBS but not commercial MBS. If the clearing bank's system is unable to distinguish between these two types of mortgage-backed securities, the collateral allocation process may require a dealer's manual intervention. Similarly, a clearing bank's system for distinguishing between the credit ratings of corporate bonds may not be sufficiently granular to accommodate the rules

The collateral allocation systems used by the clearing banks do not have filters that are sufficiently granular to meet some cash providers' collateral requirements.

applied by some cash providers. In such instances, dealers must manually allocate collateral to some of their deals at the CUSIP level, specifying exactly which collateral to allocate to each repo.

Another motive for a dealer to override its clearing bank's automated collateral allocation mechanism and manually intervene is the belief by the dealer that it can achieve a more efficient allocation of its collateral. Ideally, the allocation process maximizes the amount of financing that can be obtained from a given pool of collateral, or minimizes the dealer's all-in net cost of financing, including the effect of haircuts. The use of the clearing banks' automated allocation systems, and the avoidance of "manual overrides," is therefore promoted by the sophistication of the optimization algorithms used in these systems.

4.2. The Morning Unwind

Under market arrangements in place during the crisis, each morning between 8:00 and 8:30, the clearing banks would unwind all tri-party repo trades, including term and rolling repos not maturing that day.¹⁹ Recall from Section 3 that the return of cash to investors creates a need for dealers to find another source of financing until the day's trades and other outstanding trades are

settled in the evening. This financing is provided by the clearing banks, which extend intraday secured credit to the dealers in the form of repos to finance essentially all of their securities until the lenders' funds settle in the evening.

The clearing banks apply a risk management concept known as net free equity (NFE) to ensure that the market value of the dealer's securities held at the clearing bank, including the effect of haircuts, exceeds the value of the intraday loans provided to the dealer. Dealers may also keep securities that are not financed through tri-party repos in their accounts at the clearing bank, increasing their NFE.

A complete unwind of all repos, and not merely those maturing, is an operationally simple process. An alternative would be a process by which dealers could substitute collateral (including cash) into repo deals without unwinding them, in order to extract a needed security, possibly at multiple points in the business day. Through-the-day collateral substitution is prevalent in European tri-party repo markets. By contrast, the U.S. clearing banks have offered some automated collateral substitution capabilities to U.S. tri-party repo market participants only since June 2011.

Unwinds are at the discretion of the clearing bank. This significant fact was not well understood by some market participants prior to the financial crisis. In the event that a clearing bank becomes concerned about a dealer's credit quality—fearing, for example, that the dealer might declare bankruptcy during the coming day—the clearing agreement between a dealer and a tri-party clearing bank normally gives the clearing bank the right to protect itself by not unwinding. This would leave the original tri-party cash providers exposed to the dealer, but still holding the dealer's collateral.

A clearing bank's failure to unwind a dealer's tri-party repos would almost certainly force that dealer into default because the dealer would not be able to deliver promised securities. Moreover, investors would likely refuse to continue funding the dealer. Cash providers would then have possession of the securities backing the repos and could be forced to liquidate some or all of them.

A special concern is that U.S. money market mutual funds accept as repo collateral some types of securities that they are not permitted, under Rule 2a-7 of the Investment Company Act, to hold on their balance sheets. For example, an MMF may not be able to hold a ten-year Treasury note, given the regulatory maximum maturity of thirteen months for an MMF's assets.

¹⁹ On August 22, 2011, the unwind moved to 3:30 p.m. As of the end of 2011, one clearing bank does not systematically unwind the term repos of some investors.

5. Conclusion

This article reviews some key mechanics that played a role in the systemic weaknesses of the U.S. tri-party repo market revealed during the financial crisis of 2007-09. These weaknesses have proved an obstacle to industry reform efforts, which started in September 2009 and are currently incomplete.

The collateral allocation process in the tri-party repo market currently requires a considerable amount of time, partly because of the desire of some dealers to intervene in this process. In addition, the need to settle in the GCF market before the rest of the tri-party repo market only extends the length of the process. Settling in the GCF market also requires coordination between the Fixed Income Clearing Corporation and the clearing banks as well as communication between their systems. A similar form of coordination is required with the Depository Trust Company. The time required to allocate collateral makes it difficult to settle new and expiring repos simultaneously and thus to reduce the dealers' reliance on credit from their clearing banks. This factor has been an obstacle to ongoing reforms of the tri-party repo market.

The daily time gap between the unwind and rewind of repos drives much of the demand for intraday credit from the clearing banks, contributing to the fragility of the market in several ways. First, the gap between unwind and rewind means that there is a twice-daily transfer of exposure from a dealer's investors to its clearing bank, and then from its clearing bank back to its investors. This handoff can create a perverse dynamic if the dealer comes under stress, as both the cash investor and the clearing bank may want to be the first to reduce exposure to the dealer.

Moreover, if a dealer declares bankruptcy during part of the day, its clearing bank could be weakened. This could create

spillovers to other dealers that use this clearing bank for their tri-party activity, because investors may fear exposure to the clearing bank. It could also lead cash providers whose cash accounts are at the clearing bank to demand their cash on short notice, further exposing the clearing bank or promoting a fire sale of some collateral.

Finally, a dealer failure could disrupt the clearing bank's ability to function and thus undermine its ability to conduct other important payment, clearing, and settlement activities. This could not only destabilize the tri-party repo market, but also serve as a channel for transmitting systemic risk more broadly throughout U.S. and even global financial markets.

In principle, a collateral allocation process that allows for the simultaneous settlement of new and expiring repos would eliminate the gap between unwind and rewind, reducing the dealers' need for intraday credit. The clearing banks could design a collateral allocation system that achieves the various optimization objectives desired by dealers, thereby removing the incentive for them to manually intervene in the process. The resulting collateral allocation process would also need to be transparent to investors, allowing them to evaluate their own settlement risks.

The U.S. tri-party repo market is one of the most important components of the financial system. Improving the collateral allocation process and eliminating the time gap between the unwind and rewind of collateral would help reduce the fragility of the market and the amount of risk in the financial system.

Darrell Duffie has potential conflicts of interest that may be reviewed on his webpage (www.stanford.edu/~duffie/). Among these, he is a member of the board of directors of Moody's Corporation and has been retained as a consultant by the estate of Lehman Brothers Holdings Inc. on matters potentially related to the subject of this article.

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