Federal Reserve Bank of New York
Staff Reports

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Staff Report No. 616
May 2013

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JEL classification: G01, G18

Abstract

This paper studies the risk of "fire sales" in the tri-party repo market, a large and important market where securities dealers find short-term funding for a substantial portion of their own and their clients' assets. We distinguish between fire sales of assets by a dealer who, facing a run that could lead to default, sells securities to generate liquidity, and fire sales of assets by repo investors after a dealer's default has occurred. While fire sales do cause damage no matter how they arise, the tools available to lessen the harm from the two types of fire sales are different. We find that limited tools are available to mitigate the risk of pre-default fire sales and that no established tools currently exist to mitigate the risk of post-default sales.

Key words: Fire sale, repo market

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I. Introduction

The risk of "fire sales," rapid sales of assets in large amounts that temporarily depress their market prices, is a major source of financial instability. Policymakers' concern for fire sales was one of the driving forces behind the creation of the Term Securities Lending Facility and the Primary Dealer Credit Facility in 2008. Fire sales can amplify problems faced by a financial firm because the reduced sale price of the assets can result in realized losses that lead to a decrease in capital and the possible need for additional asset sales. Excessive sales by a single firm can also propagate stress to other institutions if they face margin calls and are forced to sell assets. The presence of such externalities suggests that market outcomes may not be efficient.[2] As a consequence, mitigating the risk of fire sales is an important objective in the effort to promote financial stability.

In this paper, we discuss the risk of fire sales in the tri-party repo market, a large and important market where securities dealers find short-term funding for a substantial portion of their own and their clients' assets. Because of the size of this market and the fact that some of its participants are vulnerable to runs, fire sales are particularly likely in this market. They can result if a securities dealer defaults and its secured creditors decide to liquidate the collateral—or even in the absence of a formal default if funding becomes difficult to obtain, spurring a rapid reduction in positions.

Fire sales are one of the three systemic risk concerns highlighted in a May 2010 whitepaper by the Federal Reserve Bank of New York on tri-party repo infrastructure reform (Federal Reserve Bank of New York, 2010). These three risks are 1) the market's excessive reliance on clearing-bank provision of intraday credit to complete settlement, 2) poor liquidity and credit risk management practices on the part of various classes of tri-party repo market participants, and 3) the absence of any mechanism to mitigate the risk of fire sales of collateral in the aftermath of a large-dealer default.

Progress is being made in addressing two of these three risks. Industry work currently under way will result in sharply reduced intraday credit usage by the end of 2014.[3] The required behavioral and process changes associated with this reduction are also expected to bring improvements in

[2] See Stein (2012) and Antinolfi et al. (2012), for a discussion of the welfare costs of fire sales.
[3] See http://www.newyorkfed.org/banking/riskreduction_022513.pdf.

market participants' risk management practices. However, these efforts will not mitigate the risk of fire sales of tri-party repo collateral in the event of a large dealer's default on its repo obligations. Fire sales remain a concern of regulators; the 2013 report of the Financial Stability Oversight Council points to the vulnerability of the wholesale funding markets to runs that can lead to destabilizing fire sales. Also, a recent speech by New York Fed President William C. Dudley at the 2013 Annual Meeting of the New York Bankers Association focused on the danger of spiraling asset sales during the crisis.[4]

In this paper we argue that, in the tri-party repo market, it is important to distinguish between fire sales of assets by a dealer who, facing a run that could lead to default, sells securities to generate liquidity, and fires sales of assets by repo investors after a dealer's default has occurred. While fire sales do damage no matter how they arise, the tools available to lessen the harm from the two types of fire sales are different. The risk of pre-default fire sales by dealers comes from the fact that dealers perform maturity and liquidity transformation (explained in more detail later), and they cannot expect to liquidate longer-maturity assets as quickly as their short-term funding may evaporate. In contrast, the risk of post-default fire sales by counterparties to a defaulted dealer is posed by the exemption from the automatic stay of bankruptcy that repo contracts enjoy, which means creditors may immediately take possession of collateral in a bankruptcy.[5] While this exemption is very important for the secured funding model, the lack of a process, or mechanism, to ensure an orderly disposal of the assets collateralizing repos across all creditors of a defaulting dealer could lead to rapid sales, price dislocations, and a deleveraging spiral.

The likelihood of pre-default fire sales would be reduced if dealers performed less maturity and liquidity transformation—for example, by lengthening the maturity of their repos, especially against lower-quality collateral. In addition, some tools are available to partially mitigate the impact of pre-default fire sales, such as either regular or emergency lending by the central bank, or capital and liquidity regulation that can make dealers less vulnerable to failure. However, these

[4] The 2013 FSOC annual report can be found at http://www.treasury.gov/initiatives/fsoc/Pages/annual-report.aspx. President Dudley's speech is available at http://www.newyorkfed.org/newsevents/speeches/2013/dud130201.html.
[5] The bankruptcy proceedings for most broker-dealers would be conducted under the Securities Investor Protection Act of 1970 (SIPA). Under SIPA, the Securities Investor Protection Corporation (SIPC) typically requests a temporary stay of the exercise of any right of setoff without the consent of SIPC and the SIPA trustee. The stay does not prohibit the non-defaulting party from closing out and terminating outstanding repos and using cash to cause the liquidation of a repo, but it does prohibit any person from disposing of securities acquired under a repo without such consent.

tools are limited in a number of ways and may serve to reduce, but not to eliminate, the possibility of fire sales following a dealer's default.

There are currently no established tools to mitigate the risk of post-default fire sales. Title II of the Dodd-Frank Act provides some ex post resolution tools for a systemically important broker-dealer, but these might not be invoked, creating possibly damaging uncertainties. Mitigating the risk of post-default fire sales requires addressing the creditors' collective-action problem, something that would likely need to involve some coordinating mechanism.

A famous incident, the resolution of Long-Term Capital Management L.P. (LTCM), illustrates the difficulty of setting up such resolution tools and the stress that can arise when these tools cannot be relied upon. In 1998, when LTCM appeared to be on the verge of default, the President of the Federal Reserve Bank of New York at the time, William McDonough, convened a meeting of top Wall Street firms, many of whom were creditors to LTCM. These firms understood that a failure of LTCM could lead to massive fire sales of the assets that served as collateral for LTCM's repos.[6] Eventually, a group of 14 of the firms agreed to purchase 90 percent of LTCM, with each providing capital in various amounts, totaling $3.625 billion. LTCM was then slowly wound-down, with the new owners making a small profit on the transaction.[7]

In this instance a market-organized solution was set up to prevent the fire sales that would otherwise have occurred, but only ex post. The stress experienced by financial markets at the time, despite the ultimate success of the rescue of LTCM, underscores the need for a well-established arrangement to be set up in advance.

To date, research on post-default fire sales has focused on the role of, and potential changes to, bankruptcy law (see, for example, Acharya, Anshuman, and Viswanathan [2013], Antinolfi et al. [2012], Duffie and Skeel [2012], or Roe [2011]).[8] However, the prospect of changes to bankruptcy law seems remote, and some aspects of the special treatment of repos may be highly desirable for fostering market liquidity. For example, close-out netting is essential for the ability of financial

[6] See transcript of the Sept 29, 1998, meeting of the FOMC, notably pages 100 and 102-3.
[7] See Fleming and Liu (2013).
[8] Martin, Skeie, and von Thadden (2010) study pre-default fire sales that can lead to the bankruptcy of a dealer.

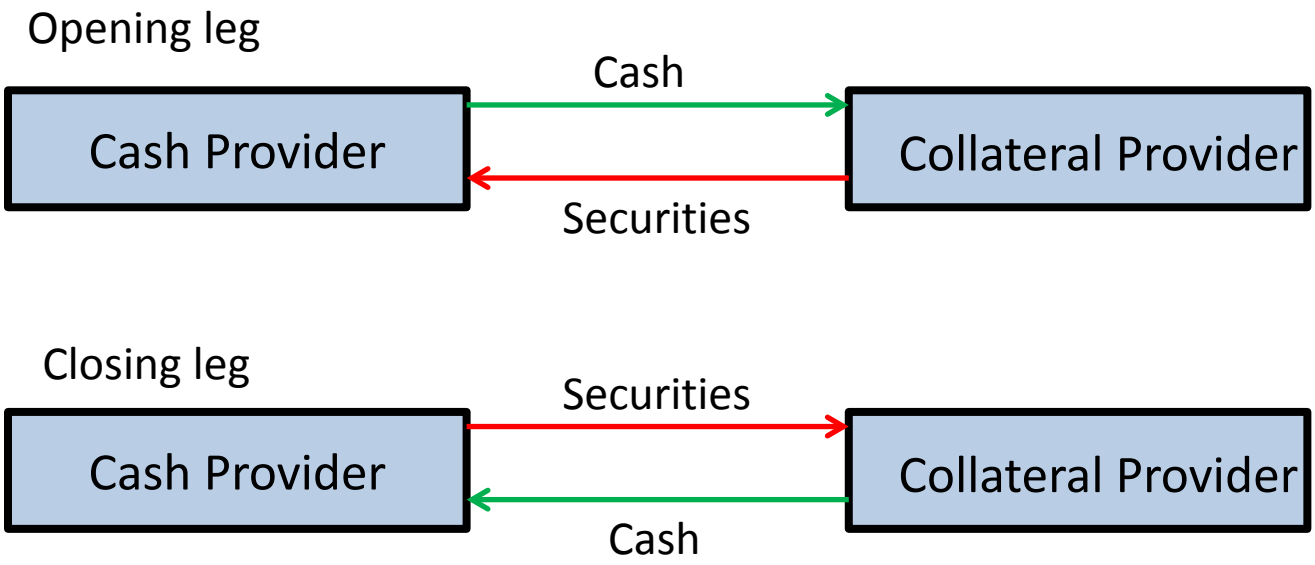
market participants to hedge. In addition, changes to bankruptcy law would not help address the risk of pre-default fire sales and could even increase this risk, as lenders would have stronger incentives to stop lending to a counterparty before a default occurs. Instead, our framework suggests that to reduce the likelihood of fire sales and their consequences, one needs to think of this risk both pre- and post-default. It also suggests that mechanisms to mitigate the risk of fire sales can be created within the context of existing bankruptcy rules.

The remainder of the paper is structured as follows. Section II describes the problem of fire sales in the tri-party repo market. Section III distinguishes between pre- and post-default fire sales. Section IV presents some quantitative work on the time that may be necessary to liquidate tri-party collateral without price impact and the possible losses associated with such liquidation. Section V discusses available tools to address fire sales. Section VI describes the links between pre- and post-default fire sales. Section 7 concludes.

II. The problem of fire sales in repo markets

In this section, we provide a brief overview of repo markets and review events from the 2007-09 financial crisis that illustrate the risk of fire sales. We also explain why fire sales are a particular concern in this market.

Exhibit 1



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.[9] Aside from important legal distinctions concerning bankruptcy treatment (discussed in more detail below), a repo is similar to a collateralized loan.[10] Exhibit 1 shows a basic repo transaction. For the opening leg of the repo, an institution with cash—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.

Fire sales during the 2007-09 financial crisis

Shleifer and Vishny (1992) define a fire sale as the forced sale of an asset at a dislocated price. Price dislocation typically occurs if a large amount of assets is sold in a short period of time. Fire

[9] Under the English-law master agreements for repos, the requirement is to repurchase the same or equivalent securities, where "equivalent" means fungible.
[10] This paper focuses on U.S. insolvency proceedings. The treatment of repo in bankruptcy can differ in other jurisdictions.

sales are a broad concern that extends well beyond the repo market.[11] Nevertheless, stress in the repo market during the financial crisis of 2007-09 provides striking examples of the kind of dynamics discussed in this paper. The damaging effects of these fire sales led to the creation of the Term Securities Lending Facility and the Primary Dealer Credit Facility in March 2008.

On February 28, 2008, Peloton Partners, a London-based investment manager, revealed that it had been getting margin calls and that creditors had begun demanding larger haircuts on mortgage-related collateral. Peloton announced that it was shutting down one fund (Peloton ABS Fund) and would shortly begin liquidating that fund's assets and closing a second fund (Peloton Multi-Strategy Fund) to further redemptions. The next day the *Wall Street Journal* reported that Peloton had had only limited success in selling assets on its own and that six of the funds' fourteen creditor banks had begun seizing collateral pledged by the funds.[12]

On Monday, March 3, Thornberg Mortgage announced that it had failed to satisfy a $270 million margin call on mortgage-secured loans and that it might have to sell assets to stay in business.[13] In this case also, the *Wall Street Journal* reported that creditors had seized "billions of dollars of collateral from [Thornberg Mortgage] and dumped [the collateral] onto an already turbulent bond market. …"[14]

Both Peloton and Thornberg liquidated subprime-mortgage-related securities at levels significantly lower than where they had been previously marked. The unexpectedly low prices prompted a reduction in collateral marks across many non-agency mortgage-backed securities that sparked additional liquidations as borrowers struggled to meet margin calls.

[11] See, for example, Manconi, Massa, and Yasuda (2012) and Merrill, Nadauld, Stulz, and Sherlund (2012) for empirical evidence on fire sales.
[12] "Mortgage Rout for a Hotshot Hedge Fund," *Wall Street Journal*, February 29, 2008, and "Banks Seize Assets of Peloton Hedge-Fund Firm," *Wall Street Journal*, March 1, 2008.
[13] "Will Thornberg Join Failed Lenders?" *Wall Street Journal*, March 4, 2008.
[14] "REIT Lender Thornberg Sees Collateral Seized," *Wall Street Journal*, March 8, 2008.

The deleveraging spiral claimed another victim on Thursday, March 6, when a leveraged investment fund (Carlyle Capital) sponsored by Carlyle Group, a private-equity firm, failed to meet creditor margin calls.[15] The fund was capitalized with $940 million of investor equity and $21.8 billion of borrowed money (making for a 24-to-1 leverage ratio) and invested in "somewhat obscure and thinly traded" securities.[16] During the following week, creditors began to liquidate the fund's collateral, selling as much as $5.7 billion of securities by Monday, March 10.[17] The sales were later cited by both the *New York Times* and the *Wall Street Journal* as a significant factor in the collapse of Bear Stearns. The *New York Times* reported that when the CEO of Bear Stearns appeared on television in an attempt to calm fears that the firm was in trouble, "Skittish lenders were already calling in loans made to Carlyle Capital …. Soon the attention spread to Bear Stearns as market players began to question the firm's ability to finance itself, sending the stock into a tailspin."[18] The *Wall Street Journal* reported, "The disclosure by Carlyle Capital [that it could not meet margin calls from its bankers] proved to be the spark that set a wildfire through mortgage markets and other parts of the financial system. Carlyle Capital held $21 billion in mortgage-backed securities, and investors feared the firm or its bankers would dump them. That roiled mortgage markets and set off fears of wider financial contagion. This chapter of the credit crisis culminated in the emergency sale of Bear Stearns Cos. to J.P. Morgan Chase & Co. for just $236 million."[19]

It is striking to consider that the initial disruptions were caused by relatively small institutions but that the stress subsequently spread to much larger firms. This risk of contagion led to the creation

[15] *Wall Street Journal*, March 7, 2008.
[16] "Carlyle Fund in Free Fall as Its Banks Get Nervous," *Wall Street Journal*, March 14, 2008.
[17] "No Delay: Wall Street Got Tough with Carlyle Capital – Despite Fund's Plea, Dealers Moved Fast to Protect Positions," *Wall Street Journal*, March 12, 2008, and "The Bear Stearns Fallout: With Street Watching, 'Repo' Trading is Light – Market That Turned on Bear Stearns Remains Cautious," *Wall Street Journal*, March 18, 2008 (reporting that $16 billion in mortgage-related assets owned by Carlyle Capital had been seized by repo creditors).
[18] "Run on Big Wall Street Bank Spurs U.S.-Backed Rescue," *New York Times*, March 15, 2008.
[19] "Fed Fix Works for Now – Mortgage-Bond Market Breathes Sigh of Relief, But the Calm Is Fragile," *Wall Street Journal*, March 20, 2008.

of the Term Securities Lending Facility and the Primary Dealer Credit Facility, both of which played an essential role in mitigating subsequent stress in repo markets.[20]

The risk of fire sales in the tri-party repo market

The tri-party repo market is a particularly large and important segment of the U.S. repo market.[21] At the end of 2012, the tri-party repo market was used to finance close to $2 trillion of securities.[22] In this market, the collateral providers are the dealer subsidiaries of large, complex financial institutions. Many of these dealers depend on the tri-party repo market as a way to fund their portfolios of securities and those of their clients. Dealers use this market to obtain short-term financing at a low cost and in a manner that preserves more or less continuous access to their securities to facilitate deliveries and receipt of securities. Cash providers in this market are primarily money market mutual funds (MMFs), securities lenders[23], and other institutional cash providers such as mutual funds, insurance companies, corporate treasurers, and state and local government treasurers.[24] 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 all tri-party repo lending.

The tri-party repo market owes its name to the fact that a third party facilitates repo settlement. In the United States, this third-party role is fulfilled by government securities clearing banks, of which there are currently two: Bank of New York Mellon and JP Morgan Chase.[25] The clearing banks settle tri-party repo transactions through transfers across cash and securities accounts on their books. Specifically, they settle the opening leg of a tri-party repo transaction by transferring securities from the dealer's securities account to the cash investor's securities account, and by transferring funds from the investor's funds account to the dealer's funds account. Movements in

[20] See Fleming, Hrung, and Keane (2009) for more details about the Term Securities Lending Facility and Adrian, Burke, and McAndrews (2009) for more details about the Primary Dealer Credit Facility.
[21] See Copeland, Martin, and Walker (2010) and Copeland, Duffie, Martin, and McLaughlin (2012) for more detail on the tri-party repo market.
[22] Volume data for the market are available at http://www.newyorkfed.org/banking/tpr_infr_reform_data.html.
[23] In the United States, securities loans are typically done against cash collateral. Securities lenders invest the cash collateral in a variety of products, including repos.
[24] We use the terms "cash providers," "cash investors," and "repo investors" interchangeably.
[25] The number of banks in the business of clearing government and agency securities has decreased over time, from nine in 1980 to two today, notably because of mergers. The concentration is likely due to the presence of economies of scale in this business.

the opposite direction occur on the closing leg of the repo. In addition to offering settlement and custodial services, clearing banks provide collateral management services, such as daily revaluation of assets, daily re-margining of collateral, and allocation of the borrower's collateral to its lenders in accordance with the lenders' eligibility and risk management constraints.[26] As explained by Garbade (2006), clearing banks also ensure that the collateral will be available to cash providers if a dealer defaults.

The risk of fire sales is a particularly acute concern in the tri-party repo market because of the size of dealers' portfolios and the strong incentives for some lenders to sell collateral quickly in a default event. Large dealers' repo books currently range between $100 billion and $200 billion and, in some cases, reached peak levels in excess of $400 billion prior to the financial crisis. There are currently no external constraints in place to prevent dealer repo books from reverting back to comparable peak levels in the future. For positions this large, even the liquidation of collateral usually viewed as liquid, such as agency mortgage-backed securities (MBS), could prove challenging over a compressed time frame. Additionally, approximately 15 percent of the assets financed in this market, almost $300 billion at the end of 2012, are private obligations that are not backed by the U.S. government or its agencies and that tend to exhibit significant price volatility and illiquidity when market conditions are strained.

Fire sales in the tri-party repo market present a risk to financial stability because they affect all holders of the assets, even those beyond the tri-party repo market. Rapid sales will exert downward pressure on the prices of these assets. Other institutions holding these assets will see their capital eroded and may have to delever.[27] Similarly, institutions that have pledged these assets as collateral could face margin calls and may be forced to sell assets. Because of the size of the market and the many similar securities used as collateral by its participants, such a cycle of sales and price declines could serve as a channel of risk transmission within and beyond the tri-party repo market, creating significant losses for all holders of the assets undergoing fire sales. The resulting financial market stress could have a negative impact on the real economy, as happened in 2008.

[26] These services are all provided for a fee.

[27] This type of dynamic was first studied in Kiyotaki and Moore (1997). See also Adrian and Shin (2010) and Greenwood, Landier, and Thesmar (2012).

Some of the largest lenders in the tri-party repo market, such as MMFs and securities lending agents, are themselves potentially subject to runs by their own clients. For example, the Reserve Primary Fund experienced a run the day after Lehman Brothers Holdings declared bankruptcy in September 2008, driven by investor concerns about the Reserve Primary Fund's holdings of Lehman debt. As the Reserve Primary Fund "broke the buck" and suspended withdrawals, many other money funds experienced runs. Separately, a number of securities lending agents using commingled accounts lacked sufficient liquidity to meet client demands in 2008 as parties sought to unwind securities lending transactions. This resulted in a need to limit cash outflows through use of redemption gates or through repayment in kind, using securities purchased with cash collateral.

All of this suggests another avenue of contagion and fire sales in the event of a dealer default in the tri-party repo market. Other dealers could face difficulties in obtaining repo funding if many cash investors started exiting the market because of runs by their shareholders and creditors. With funding in such short supply, non-defaulting dealers may have to sell securities to avoid defaults. More generally, dealers are vulnerable to any shock that would cause a large class of investors (such as MMFs, for example) to quickly reduce their investment.

In addition, many tri-party repo lenders face operational or regulatory constraints that create strong incentives to liquidate assets immediately after taking possession of them following a dealer's default. Operationally, many investors lack credible plans to ensure orderly disposal of collateral seized as a result of a dealer default. From a regulatory perspective, some tri-party repo investors accept as collateral securities that they are not permitted to own outright or that would, in the aggregate, quickly put them in violation of portfolio composition rules (for example, by significantly extending average maturities). A counterparty bankruptcy could instigate a run on the repo investor, if that institution's own investors become concerned about the change in risk profile that results from having to take possession of the collateral backing the repo. Regardless of their trigger, such runs would create a large and sudden need for liquidity that may require rapid sales of the collateral when no other source of backup liquidity is available.

III. Fire sales pre and post dealer default

Fire sales can occur whenever a large volume of securities is sold in a short amount of time. In the tri-party repo market, this could occur under two distinct sets of circumstances: 1) if a dealer under stress needs to sell assets it can no longer finance, before it potentially defaults; and 2) after the dealer has defaulted, if its repo counterparties sell the repo securities quickly. As noted above, the two types of fire sales could happen simultaneously—for example, if a large-dealer default triggers a broader pullback by cash investors in the repo market, which may force other dealers to sell their assets. While the economic impact of fire sales is the same regardless of whether dealers or lenders are selling, the types of tools that are effective in mitigating fire sale risk will differ, depending on whether the seller is a dealer or a creditor.

Pre-default fire sale

Pre-default fire sales occur when a dealer loses access to market sources of secured funding. This might occur either for systemic or idiosyncratic reasons. In a systemic scenario, a shock, such as a pullback of lenders from funding a specific type of illiquid and hard-to-value asset, could reduce all dealers' access to secured funding and create pressure to sell assets in order to generate liquidity and/or reduce balance sheet size. Gorton and Metrick (2012) document a large increase in haircuts in the bilateral repo market. An increase in haircuts reduces the funding that can be obtained for a specific amount of assets and could trigger the sale of some assets. Krishnamurthy, Nagel, and Orlov (2012) provide evidence that MMFs stopped funding non-agency asset-backed securities (ABS) and MBS in the fall of 2008, as the financial crisis reached its peak and many MMFs experienced runs by their shareholders. Interestingly, these authors do not find significant increases in haircuts in the tri-party repo market.

Idiosyncratic loss of access to secured funding would typically occur when lenders run from a dealer because of concerns about its solvency. Copeland, Martin, and Walker (2010) provide evidence of a sharp reduction in the amount of tri-party repo funding at Lehman in the days before the holding company declared bankruptcy. Their paper also provides evidence consistent with Gorton and Metrick (2012) and Krishnamurthy, Nagel, and Orlov (2012), suggesting that, in the

bilateral repo market, investors appear more willing to increase margins when a repo becomes more risky because either the borrower or the collateral becomes more risky. In contrast, tri-party repo market investors did not adjust either margins or quantities in a gradual way. They apparently either provided a consistent amount of funding, or abruptly reduced their funding. This evidence suggests that the tri-party repo market may be at greater risk of fire sales than the bilateral repo market, at least given the current set of market participants.[28]

As mentioned, dealers face the risk of pre-default fire sales because they perform maturity and liquidity transformation. Maturity transformation occurs because the repos have a much shorter tenor than the maturity of the securities that serve as collateral. Liquidity transformation occurs because the time it would take to sell the securities backing the repos without affecting prices exceeds the duration of the repo funding. For example, a portfolio of securities that might take ten days to liquidate without price impact may serve as collateral for a five-day repo.

Dealers performing maturity and liquidity transformation in the tri-party repo market could be solvent but illiquid. The value of the securities they hold might exceed the face value of the repo if the securities are held to maturity or sold in a well-functioning market. If, however, the supply of these securities temporarily exceeds the demand by a large amount, then their price might drop to a point where the securities are worth less than the face value of the repo they collateralize. Martin, Skeie, and von Thadden (2012) model dealers that finance themselves through repos and study how a loss of funding due to a run can force a dealer to sell assets and potentially trigger fire sales.

Post-default fire sale

Post-default fire sales occur after a dealer has defaulted when its repo counterparties sell the collateral quickly. As mentioned, repo counterparties benefit from a special protection in case of bankruptcy because repos are exempt from the automatic stay.[29,30] Because of the exemption, repo

[28] Clearly, the risk of fire sales in the bilateral repo market would increase if the set of tri-party repo investors that currently create fire sale risk in that market were to start using the bilateral market more extensively.
[29] As noted above, a registered broker-dealer is resolved under SIPA, and SIPA imposes a stay on liquidation of securities collateral. It is expected, however, that SIPC will lift this stay in a short time period. Such a short stay would delay, but likely not mitigate, the fire sales.

counterparties can close out the repo and liquidate the repo securities soon after the bankruptcy of their dealer counterparty. This feature of repo makes it a relatively attractive and liquid investment vehicle from the lender's perspective and has undoubtedly contributed to the growth of repo market liquidity and volume over time. Indeed, the exemption from the automatic stay makes the repo counterparties' claims extremely safe in a "microprudential" sense, as the claims are backed by collateral that can be sold quickly even in the event of a bankruptcy of the dealer. However, this safety comes at a "macroprudential" cost of increasing fire sale risk.

Repo creditors of a defaulting dealer have the right to sell the repo securities, but they are not required to do so. Upon a default event, industry-standard master repo agreements (MRA and GMRA) require the cash investor to do one of two things: either 1) immediately sell the securities and net the purchase price against the amount owed to it by the defaulted dealer, or 2) if not selling immediately, determine the market value of the securities and net that value against the amount owed to it by the defaulted borrower. In this latter case, the lender has some discretion over when to sell the assets. If creditors to a defaulted dealer can take the time to sell the collateral at a measured pace, fire sales need not materialize. Nevertheless, several factors make post-default fire sales likely in the tri-party repo market: 1) the size of the portfolio being financed; 2) the incentives some creditors would likely have to sell their collateral very quickly, owing to a combination of their funding profile and their regulatory requirements; 3) the desire to avoid disputes about the "market value" of the securities calculated in the close-out process; and 4) the collective-action problem faced by repo lenders (explained below).

As noted above, large dealers' repo books currently range between $100 billion and $200 billion. For most asset classes, the volume of collateral that would potentially be liquidated greatly exceeds the total daily volume traded on a typical day. In section 4, we conduct a value-at-risk (VaR) analysis that illustrates the potential shortfall from liquidating the portfolio of a hypothetical large dealer.

[30] In bankruptcy law, the purpose of the automatic stay is to prevent the destruction of value that can occur when creditors try to indiscriminately seize the assets of a bankrupt firm. See Garbade (2006) for an account of the events that led to the exemption from the stay in the United States. Antinolfi et al. (2012) study a model in which exemption from the stay can lead to fire sales.

The largest dealers transact with a number of different tri-party repo lenders. Copeland, Martin, and Walker (2010) show that, until a few days before Lehman's declaration of bankruptcy, its U.S. broker-dealer subsidiary had more than sixty different cash investors.[31] Upon the default of a large dealer, many investors would have incentives to sell their assets quickly and might not take into account the combined effect of their sales on the market price of the assets. In that sense, the investors face a collective-action problem. They would all be better off if they could coordinate their actions to minimize the effect of their sales on the price of the collateral they are trying to liquidate. Absent this coordination, their actions will result in excessive declines in the price of their collateral, which can be costly for all of them. In addition, some investors may be unable to dispose of assets at a moderate pace, even if they wanted to. For example, MMFs and securities lenders may be forced to sell assets to meet the redemption requests of their own investors.

It is worth noting that while pre-default fire sales are the result of a sharp withdrawal of funding, which can be associated with a run, the same is not true for post-default fire sales. Post-default fires sales are triggered by the default of a large dealer, regardless of the cause of that default. In many cases, we might expect a dealer default to result from a loss of funding similar to a run. However, it is also possible that an abrupt event, such as fraud or significant unexpected investment losses, could move a dealer quickly to default, resulting in post-default fire sale despite the absence of pre-default fire sales.

IV. Fire sale risk for different asset types

In this section, we consider how the risk of fire sales could materialize, depending on the types of assets that are funded in the tri-party repo market. Ideally, we would like a method to estimate the price impact of a given volume of securities in a short amount of time. Unfortunately, there is no standard way to estimate this price impact statistically and thus evaluate the risk of fire sales.[32] So we are forced to use an indirect approach instead.

[31] Note that this broker-dealer subsidiary did not declare bankruptcy.
[32] Greenwood, Landier, and Thesmar (2012) consider the effect of sales on asset prices. They assume a sales volume of $10 billion leads to a price change of 10 basis points for all assets. See also Amihud (2002) for an attempt to estimate the price impacts of sales for stocks.

Table I.

Asset Class	Dollar Value in Billions	Share of Portfolio
U.S. Treasuries and Strips	70.6	35.3%
Agency debt	10.6	5.3%
Agency MBS and CMO	88.4	44.2%
Corporate bonds	6.8	3.4%
Equities	11.0	5.5%
ABS	3.8	1.9%
All other	8.8	4.4%
Total	200	100%

First, we consider how long it would take to liquidate different segments of a hypothetical portfolio of $200 billion, displayed in Table I, which is representative of the portfolios of the largest dealers in the tri-party repo market. The breakdown of assets is chosen to replicate the publically available data on the collateral composition of the overall tri-party repo market for December 2012. For each asset class, the amount of collateral that can be liquidated on a given day is provided in Table II. The numbers are estimates provided by market participants and the New York Fed's Markets staff. For each asset class, the liquidation horizon, shown in Table III, is determined by combining the amount of collateral from Table I with the amount that can be liquidated each day without having a material and adverse impact on the market pricing from Table II. For example, the liquidation horizon for Treasuries is 70.6 / 7.5 = 9.4 days, rounded down to 9.

This simple exercise shows that the number of days needed to liquidate some segment of the hypothetical portfolio is quite large, suggesting a high risk of fire sales. For example, the number of days necessary to liquidate the portfolio of agency MBS and collateralized mortgage obligations (CMO) is twenty-two days. The portfolio of ABS would take thirty days to liquidate.

It is worth nothing that these estimates are conservative. The assumption regarding the number of days to liquidate is for normal market conditions taking into account historical daily turnover in

each asset class and is meant to avoid signaling effects. Under stressed market conditions, liquidating most asset classes would take longer. One possible exception is Treasury securities, which tend to benefit from flight-to-quality episodes. That said, recent events in Europe suggest that even sovereign debt can become illiquid in some circumstances.

Table II.

Collateral Type	Amount that can be liquidated in one day without an adverse impact on market prices (normal market conditions)
U.S. Treasuries and Strips	$7.5 billion
Agency debt	$2 billion
Agency MBS and CMO	$4 billion
Corporate bonds	$250 million
Equities	$500 million
ABS	$125 million

Table III.

Collateral Type	Days needed to liquidate segment of hypothetical portfolio in Table I
U.S. Treasuries and Strips	9
Agency debt	3
Agency MBS and CMO	22
Corporate bonds	27
Equities	22
ABS	30

Some sub-segments of these broad asset classes may be harder to liquidate than others. For example, Strips and TIPS would be much harder to liquidate than other Treasury securities. Our assumptions regarding days to liquidate apply to the most liquid assets in each asset class. So high-yield corporate bonds or some less liquid equities would take longer to liquidate than our assumptions suggest.

Next, we consider a VaR approach for some of the asset classes of the hypothetical tri-party portfolio. This approach uses two inputs: the amount of the asset that can be liquidated on a given

day without price impact, as calculated above, and the price volatility of an asset. These are then used to evaluate the potential loss of principal associated with the sale of the assets.

As already noted, the time necessary to liquidate the collateral will depend on the liquidity of the asset and the amount being liquidated, two dimensions likely relevant to the risk of fire sales. So while this approach does not allow us to directly measure the potential impact of fire sales, it may indicate the risk created by each asset class. It may also inform us about the relative risk of different asset classes.

Table IV.

Collateral	Potential Collateral Shortfall (in millions)	Liquidated Value (in millions)	% Shortfall	25 %-ile	Median	75 %-ile
U.S. Treasury (Strips)	$679	$62,600	0.96%	2% (2%)	2% (2%)	2% (3%)
Agency debt	$69	$6,468	0.65%	2%	2%	4%
Agency MBS (CMO)	$2,385	$85,615	2.70%	2% (2%)	2% (3%)	3% (7%)
Corp bond	$627	$6,180	9.23%	3%	5%	15%
Equity	$2,550	$8,449	23.18%	5%	8%	15%

For each asset class, we use a statistical method described in the appendix to measure the difference between the value of the collateral at the time the liquidation starts and the total proceeds from liquidation. Average daily volatility of an asset is defined as the standard deviation of the daily return on an index representative of this asset over a given period of time. We use a 120-day average daily volatility over the period September 2 to December 31, 2008.[33] This is a measure of average volatility during a stressed period, rather than a measure of extreme volatility. We assume that the same amount of collateral is liquidated each day during the liquidation period.

[33] While the time period corresponds to 120 calendar days, the number of trading days is 87. The indexes we use for each asset class considered are provided in the appendix. We did not include ABS for this exercise because we could not find an appropriate price index.

Assuming that asset price changes (returns) follow a normal distribution, with mean zero and volatility corresponding to our value of average daily volatility, we can calculate a distribution of prices over a given liquidation horizon.[34] This allows us to determine the total value generated by the sale of the portfolio and compare it to the value of the portfolio at the beginning of the liquidation period. The shortfall we report in Table IV is such that losses of this size or greater occur with 1 percent probability. Table IV also displays the 25th, median, and 75th percentile haircut for each asset class.[35]

Our shortfall analysis suggests that losses incurred in the process of liquidating nongovernment and agency collateral could be substantial. Even for some government and agency collateral, such as agency MBS and CMO, losses could be non-negligible. Again, this analysis is conservative for a number of reasons. For tractability, we assume a normal distribution of the returns of the assets we consider. But it is widely recognized that the normal distribution understates the probability of extreme events in this context and, accordingly, the measure of shortfall. Also, while we use a volatility measure for a fairly stressed period, the fact that this measure is an average over 120 days understates the volatility on the most stressed days. As already noted, our liquidation horizons are conservative, which also reduces the potential shortfall. Given all these limitations, it is striking that the potential shortfall associated with nongovernment and agency collateral is quite large compared to the haircut applied in the tri-party repo market.

V. Tools to mitigate fire sale risk

This section discusses tools to mitigate fire sale risk. In addition to considering separately pre- and post-default fire sales, it is convenient to distinguish between two sets of collateral: 1) government securities, which are backed by the full faith and credit of the federal government, and agency securities that enjoy government support, and 2) risk assets, which are issued by private entities and do not have government backing. Government and agency securities include Treasury

[34] Since a longer liquidation horizon implies a larger volatility, the "root-t rule" is used to adjust the daily volatility measure for each day of the horizon. See the appendix for more detail.
[35] Monthly haircut data for the tri-party repo market are available at http://www.newyorkfed.org/banking/tpr_infr_reform.html

securities, debentures issued by Fannie Mae, Freddie Mac, and Ginnie Mae, and agency mortgage-backed securities. Risk assets include all other securities financed in the tri-party repo market, such as corporate bonds, equities, asset-backed securities, and whole loans.

Government and agency securities tend to benefit from a flight to quality in the event of broader market stress.[36] Nevertheless, given the quantity of these securities that are financed by many of the largest individual dealers, fire sale conditions could materialize, even for government and agency securities, if the collateral is liquidated in a disorderly manner.[37] In addition to differences in their relative liquidity characteristics and credit profiles, the two sets of collateral receive different regulatory treatment, as described below.

The distinction between pre- and post-default fire sales, and between government and agency securities and risk assets, provides a helpful framework for analyzing the range of policy options we have identified for mitigating the risk of fire sales.

A. Pre-default fire sale risk

As noted in section III, pre-default fire sales occur because dealers perform maturity and liquidity transformation. In this case, we are concerned with solvent dealers that lose access to market sources of funding and attempt to liquidate large quantities of securities. The risk associated with maturity transformation can be reduced by lengthening the maturity of repos and making sure that only a small volume mature on any given day. A tool to address the risk related to liquidity transformation is a liquidity backstop. Indeed, the discount window is designed to play precisely this role for banks. We consider both types of tools in turn.

"Laddered" term funding of assets

[36] We assume that government and agency securities continue to exhibit better credit and liquidity characteristics than risk assets over time, and we do not explicitly contemplate the possibility of a sovereign risk crisis (in which the value of the sovereign guarantee collapses to zero) or a run on housing-related assets.

[37] In 2012, individual dealers financed as much as $84 billion of Treasuries, $21 billion of agency debt, and $124 billion of agency MBS.

Since maturity transformation is central to the liquidity risk faced by dealers in the tri-party repo market, one option to reduce the risk of pre-default fire sales would be to make sure that dealers' tri-party repo books are sufficiently termed out and "laddered." Laddering refers to the idea that a small amount of repos mature each day. For example, a portfolio consisting of $6 billion in risky collateral could be termed out for 60 days. In addition, the portfolio could be broken down into 60 repos of $100 million each and laddered so that only one such repo matures on any given day. Extending and staggering the maturities for repos against risk assets would ensure that a dealer cannot immediately lose all financing for its assets, which would reduce the pressure to sell. Moreover, if a dealer is not able to obtain new funding, laddering allows a dealer to sell its assets at a measured pace, reducing the risk of a downward price spiral.

Further stability could be achieved if the repos are structured as "evergreens," providing lead time for recovery or resolution of the dealer. An evergreen repo is a contract that automatically renews on previously set terms. For example, a sixty-day evergreen repo struck today becomes a new sixty-day repo each successive day until one of the counterparties decides not to renew. The repo then terminates sixty days after the date of nonrenewal. The benefit of evergreens is that they give dealers time to find an alternative source of funding, or to sell assets, when the contract is not renewed. Evergreens, combined with laddering, are particular useful for funding risk assets, which may require some time to sell without affecting market prices.

Regular lending authority

Regular borrowing from the discount window, pursuant to Section 10B of the Federal Reserve Act, could be used by banks to provide funding to affiliated solvent dealers. In such a case, the bank affiliate could borrow from the discount window against its own collateral, or collateral received from the dealer affiliate through a reverse repo, and then use this funding to lend to the dealer.

Dealers may be able to get this type of funding from bank affiliates for their government and agency securities, but would likely face difficulty obtaining funding for their risk assets. Indeed, Sections 23A and B of the Federal Reserve Act, as implemented through Regulation W, put strict constraints on inter-affiliate transactions, from which inter-affiliate repos backed by U.S.

government and agency collateral are exempt. In practice, these constraints mean that the largest broker-dealers have very little capacity to fund risk assets through their bank affiliates' access to the discount window. An additional potential constraint is that some of the largest dealers are affiliated with small banks that have small balance sheets. The amount of collateral that such a small bank can finance is constrained by its capital leverage limit.

Emergency lending authority

In circumstances determined by the Board of Governors to be "unusual and exigent," and subject to the constraints imposed by the Dodd-Frank Act described below, the Federal Reserve could in theory provide a temporary backstop source of funding to solvent dealers against a pledge of securities collateral and, in that way, facilitate an orderly deleveraging process. This was done, for example, with the introduction of the Primary Dealer Credit Facility (PDCF) in 2008 to backstop the tri-party repo market.[38] A facility such as the PDCF was needed because securities dealers, including primary dealers, do not have direct access to the discount window.

It should be noted, however, that this type of emergency lending would be more difficult to set up today than it was in 2008. Indeed, under the provisions of the Dodd-Frank Act, such lending now can only take the form of a program with broad-based eligibility and can only be made available to solvent borrowers. Moreover, the collateral must be sufficient to protect taxpayers from losses and must be given a lendable value that ensures such a result. Finally, the lending cannot be structured to remove assets from the balance sheet of a single and specific company or established to allow such a company to avoid bankruptcy. Explicit approval from the Secretary of the Treasury is required prior to the extension of any credit.

Market participants have some degree of uncertainty as to when these tools would be used, which may lessen their effectiveness in instilling confidence and in reducing the desire of investors to run. Indeed, investors who are concerned that such lending may not be forthcoming, or may be available only with a delay, would rationally want to reduce their exposure to a troubled dealer

[38] See Adrian, Burke, and McAndrews (2009).

before other investors do. Hence, the incentives to be first in line remain as long as the uncertainty persists.

Another potential weakness limiting the effectiveness of this type of backstop is that it may suffer from "stigma," as was observed in the case of the discount window during the fall of 2007. The term auction facility was created in part to mitigate this stigma.[39] Valukas (2010) discusses possible stigma in the context of the PDCF.

B. Post-default fire sale risk

In the event that a dealer defaults on its tri-party repo obligations, its counterparties will exercise their rights and obligations under the master repo agreement. Investors would have the ability to sell their collateral soon after a dealer defaults. For the reasons laid out in this paper, this action would likely lead to fire sales and market instability under current market arrangements.

One way to mitigate the risk of fire sales would be for market participants to set up in advance a process, or mechanism, with the capability to manage appropriately timed sales of the assets, while also providing for the liquidity needs of the investors. Establishing such a mechanism does not necessarily require the creation of a new entity, such as a financial market utility (FMU). Nevertheless, an effective process could adopt a number of features that are frequently found, and have proved effective, in existing FMUs. In particular, this process would need to include three essential components: 1) rules to determine who would liquidate the repo securities, 2) a source of liquidity to finance the securities until they can be sold, and 3) rules for allocating potential losses associated with the sale of the securities. Each of these components is discussed in more detail below.

Rules to determine who would liquidate the repo securities

In the event a large dealer defaults, the dealer's repo investors would have the right, under current rules, to sell the repo securities soon after the default. As noted above, this action could lead to fire

[39] Armantier et al. (2011) provides evidence of stigma associated with borrowing at the discount window. See Ennis and Weinberg (2009) for a model.

sales because some classes of investors in the tri-party repo market have strong incentives to sell these assets into the market as quickly as possible. In addition, investors face a collective-action problem, as individual investors do not take into account the impact of their sales on the market price of assets.

The risk of fire sales would be mitigated if the assets serving as repo collateral were sold by an institution (or a set of institutions) that has incentives and the ability to maximize the value of these assets. This institution could take many forms. For example, it could be the clearing bank of the defaulting dealer, a large asset manager (or a consortium of asset managers), a dealer (or a consortium of dealers), or a special-purpose entity created specifically for that role (Acharya and Oncu [2013] suggest the creation of a repo resolution authority).[40]

Example for government and agency securities

This section describes one possible approach: A consortium of the largest dealers agree in advance to purchase pro rata shares of a defaulted dealer's repo portfolio and to fund these assets while conducting an orderly liquidation. This example highlights essential features of such arrangements, but other arrangements with similar features could also work.

A group of dealers could agree in advance to purchase the government and agency securities from tri-party repo investors following the default of a large dealer. The set of dealers whose default would trigger this procedure might be defined as any member of the consortium of dealers that commit to purchase the securities of a large defaulted dealer. In addition, rules could be established to specify in advance the price at which the securities would be purchased, such as the market price at close of business on the day of dealer default. The more dealers that participate in the arrangement, the fewer securities each individual dealer would be obligated to purchase. A rule set could be established ex ante that defines how the repo securities are to be divided among participating dealers in the event of a default.

[40] In each case, the institution could either act as an agent on behalf of the investors who would continue to bear the risk associated with liquidating the collateral, or it might purchase the collateral from the investors and bear the risk itself. We discuss below the rules for allocating potential losses associated with the sale of the securities.

Note that the dealers in the consortium would not coordinate their liquidation of the defaulted dealer's repo securities. This would not be necessary because the consortium dealers have the knowledge and ability to manage large portfolios of such securities.

Operationally, the clearing bank of the defaulted dealer would transfer the securities to the purchasing dealers based on the rule set. These transfers would provide cash back to the investors. Given that many tri-party repo investors base their repo investment decisions primarily on the creditworthiness of the dealer, those investors would likely be willing to finance the dealers who took possession of the collateral, assuming those dealers continue to be creditworthy institutions.

Available data help illustrate how it might be possible to structure such an arrangement to ensure that each individual dealer takes on a manageable quantity of assets. In October 2012, the ten largest dealers financed about $1 trillion in government and agency assets, and the largest portfolio was approximately $160 billion. Suppose the largest dealer defaults and the next nine largest dealers finance these government and agency assets. This would represent an increase of 15.6 percent of each surviving dealer's tri-party repo book of government and agency assets.[41] The largest and smallest surviving dealer would finance an additional $23.4 billion and $10 billion, respectively. Adding more dealers to the arrangement would reduce the amount of assets each surviving dealer would have to finance.[42]

Ex ante commitments similar to the one we outlined here do exist today. For example, the Capped Contingent Liquidity Facility (CCLF) is a mechanism in place at the Depository Trust and Clearing Corporation's MBS central counterparty. It commits solvent members to fund the portfolio of a failed firm using repos between themselves and the Fixed Income Clearing Corporation.

[41] Fluctuations of that magnitude are not uncommon in the normal course of business. Between January 1, 2011 and December 6, 2012, the top ten dealers experienced sixty-seven cases where their tri-party repo book changed by 15 percent or more from one day to the next. The corresponding number for the top twenty-five dealers is 247.

[42] It is worth noting that if multiple dealers were to default at the same point in time, this regime could become quite challenging for individual dealers to manage and may require supplementing with a liquidity backstop provided by the central bank. As described above, such a backstop would help dealers finance the government and agency securities they are unable to fund in the market.

Acharya and Oncu (2013) suggest that Treasury and agency securities might not need to be included in the repo resolution scheme because they are sufficiently liquid. While the risk of fire sales of Treasuries seems remote, we believe that this risk is material for agency securities, especially agency MBS, based on the analysis in section VI.

Example for risk assets

Orderly liquidation of risk assets following the default of a major dealer might be even more difficult to do than for government and agency securities, given the relative illiquidity, opaqueness, and price volatility of risk assets in a stressed market environment. The willingness of healthy dealers to step in to support the liquidation of government and agency securities in a stressed market environment might not extend to these assets, which would 1) take longer to liquidate in the market, 2) be subject to greater price volatility during the holding period preceding liquidation, and 3) be more difficult to fund in the absence of a PDCF-like backstop. As a consequence, the consortium idea that we described for government and agency securities may be neither feasible nor advisable for the liquidation of risk assets.

Hence, it is particularly important to have a collective mechanism to ensure the orderly, coordinated liquidation of the risk assets that served as collateral for the repos of the defaulted dealer. This could be achieved by delegating the responsibility of liquidating the repo securities to a single institution that has expertise in managing and selling assets. This institution would need to have the incentives and the tools to sell assets at a measured pace.

It is likely that, given the long liquidation horizon, these assets could be more efficiently sold through periodic auctions. There are many examples of these kinds of mechanisms in other financial markets; these are typical features of central counterparties, for example.

Source of liquidity

If the assets are liquidated at a manageable pace, they must be financed in some fashion until they are sold. For that reason, any mechanism or process designed to reduce the risk of fire sales needs

to include a robust source of liquidity. The source of liquidity may depend on the institution (or set of institutions) responsible for the liquidation of the repo securities.

Again, the liquidity could be obtained from a variety of potential sources, such as commitment from market participants, committed lines of credit from other institutions, an emergency facility set up by the official sector, or regular loans made by the central bank.

Example for government and agency securities

Government and agency securities trade in markets that are generally deep and liquid, and their risks are well understood by dealers. For these reasons, liquidity for these securities could be provided by the healthy dealers who may rely, indirectly, on the investors of the defaulted dealer. In our consortium example, the repo lenders of a bankrupt dealer should in principle be willing to finance, at least temporarily, the failed dealer's assets if they are transferred to healthy dealers. Indeed, the risk investors would face in such a case would be smaller than the risk involved in lending to the dealer that just failed. Nevertheless, in the event a solvent member of the consortium would find it difficult to obtain sufficient private-sector financing for its share of the assets, the pre-default tools discussed in the previous section may be available to allow for a gradual disposition of these assets.

Under this approach, a centralized liquidation agent may not be necessary, owing in part to the expertise dealers have in managing government and agency securities and to the liquidity of these assets. The dealers would own the assets, dispose of them as they see fit under pre-defined contractual arrangements, and bear any losses on sales of those assets according to pre-agreed procedures (discussed below).

Example for risk assets

Any orderly liquidation mechanism would need to be far more robust for risk assets and would likely need to involve a centralized liquidation agent. If the institution conducting the liquidation of the collateral were a bank, such as the clearing bank of the defaulted dealer or a special-purpose bank designed specifically for that task, it may have access to regular discount window lending as

a source of liquidity, if it had purchased the repo securities from the investors of the defaulted dealer.[43] If the liquidation institution were not a bank, it would need to rely on committed lines of credit from financial institutions such as banks or dealers.

For example, Acharya and Oncu (2013) propose that a repo resolution authority would purchase the assets from investors at conservative haircuts. The purchases would be financed by a repo resolution fund, to which repo lenders would contribute. Hence, liquidity in this case would be provided in part by the investors, in the form of conservative haircuts, and in part by the repo resolution fund.

The need to access a robust source of liquidity could increase the average cost of financing risk assets in the tri-party repo market, which might lead dealers to finance a smaller quantity of them. Currently, several dealers are financing between $20 billion and $30 billion of risk assets in the tri-party market. The cost of committed credit for portfolios of that size is substantial. Even the largest designated financial market utilities (DFMUs) in the United States do not maintain committed lines of credit that large.[44] If committed lines were pursued, it would be important to consider whether these lines are provided by institutions likely to come under stress at the same time as the large dealers active in the tri-party repo market.

Rules for allocating potential losses

A process for facilitating orderly liquidation of assets across many investors would be expected to reduce aggregate losses on the disposition of the assets. Nevertheless, any solution would need to feature rules and procedures for allocating potential losses resulting from the liquidation across market participants.

[43] Access to the discount window would not be available if such a bank were managing the liquidation on behalf of the investors but did not own the securities.

[44] There are currently eight DFMUs in the United States (http://federalreserve.gov/paymentsystems/designated_fmu_about.htm). The Chicago Mercantile Exchange has the largest amount of committed lines of credit of all the DFMUs. In November 2012, it increased its committed lines of credit to $5 billion.

Example for government and agency securities

A large position in government and agency securities could take time to liquidate in an orderly manner, and the potential for mark-to-market or even realized losses exists. However, several factors make that risk relatively small. Government and agency securities are generally less subject to price volatility than risk assets, in part because the former are traded in deep and liquid markets. Treasuries in particular tend to be in high demand in the event of broader market stress and are beneficiaries of a broad flight to quality. In addition, margins on government and agency collateral in the tri-party market today would be adequate, in most cases, to absorb the likely scope of mark-to-market losses, provided there is no undue pressure to liquidate the securities immediately (see section IV).

In the case of the consortium example, dealers would purchase the securities from the investors and would bear any resulting losses. The arrangement could be structured in a way that allows dealers to keep some or all of the gains from the liquidation if it is profitable, compensating them for the risk they take.

Other solutions may require an ex ante waterfall outlining the allocation of any losses resulting from the liquidation. These rules could include minimum margins, creation of a participant fund (with contributions from dealers, investors, or both), loss mutualization, or the passing of losses to the original tri-party repo investor post liquidation. All rules adopted in support of an orderly liquidation process could be embedded in the existing tri-party repo participant contracts and be made a requirement for participation in the market.

Example for risk assets

Sales of risk assets into a stressed market environment would be expected to generate higher market and credit risk losses per dollar than is true for government and agency securities. Notably, our analysis suggests that current haircuts may not be adequate to cover the potential scope of losses in a stress event. Given this factor, and the higher potential for losses per dollar on risk assets, clear rules to govern the allocation and management of losses realized on sales are even more important for risk assets than for government and agency securities. There are various ways

to create this buffer for such losses, including the raising of margins beyond current levels or the creation of a mandatory participant fund. One way to institutionalize the needed liquidity and loss allocation arrangements might be to establish a central counterparty (CCP) for repos against risk assets.

Acharya and Oncu (2013) envisage several ways to protect their repo resolution authority from credit losses. First, the repo resolution authority would purchase the repo securities of the defaulted dealer with a conservative margin. Second, the repo resolution authority would be able to "claw back" the difference between the amount at which the securities were purchased from investors and the liquidation value, should the latter be smaller than the former. Credit risk could be further mitigated by allowing only relatively safe securities to be included in the repo resolution scheme,[45] by requiring that repo investors meet pre-specified solvency criteria, and by imposing concentration limits on the asset types a given investor could finance.

An alternative to a market-based process for ensuring orderly, coordinated sales of assets would be to establish an ex post emergency central bank liquidity backstop for the dealer's creditors, consistent with the current statutory requirements.[46] However, we view this as an inferior option, for several reasons. First, such a backstop could give rise to significant moral hazard. Second, it may be difficult to establish an emergency liquidity backstop soon enough after a dealer's default to forestall a run (given the complexity involved in establishing backstops for creditors of a defaulted dealer post Dodd-Frank) and might therefore prove ineffective in avoiding fire sales. Finally, it might be very challenging for the Federal Reserve to lend large amounts to tri-party repo investors in a manner that secures it to its satisfaction, given the relatively low capitalization of some parts of the tri-party repo investor base.

VI. Links between pre- and post-default fire sales and self-fulfilling expectations

The link between pre- and post-default risk of fire sales is also worth considering. For example, a run on a large dealer could trigger a pre-default fire sale and, by forcing the dealer into default,

[45] The authors envisage that securities that are too risky would be subject to the automatic stay of bankruptcy.
[46] Such an emergency facility would be subject to all the constraints mentioned above.

may also lead to post-default fire sales. Conversely, the fear of losses that may be associated with a post-default fire sale could provide incentives for investors to reduce their exposure to a large dealer precipitously, which may in turn trigger a pre-default fire sale. In that sense, expectations of fire sales could be self-fulfilling: Fear of a post-default fire sale leads to a run on a large dealer, which forces the dealer to default and creates the conditions for the fire sale to occur.

Because of these dynamics, addressing the risk of pre-default fire sales would also help reduce the risk of post-default fire sales. But it would not eliminate the risk. Indeed, runs are only one of several reasons why a large dealer might default. For example, consider the hypothetical case of a large dealer that finances all of its assets with long-term repos so that the amount of maturity transformation associated with this activity is negligible. In such a case, the risk of a pre-default fire sale would be absent. However, such a large dealer could still be forced to default, for reasons such as large losses on its derivatives book or fraudulent conduct by a rogue trader. Hence, the risk of post-default fire sales would remain even if the risk of pre-default fire sales had been completely eliminated.

Note also that sales of assets pre-default, if they occur at a sufficiently slow pace, would reduce the risk of post-default fire sales should the dealer eventually fail. Indeed, the more assets that are sold before the default occurs, the fewer the assets that are put to investors who have incentives to sell them quickly.

Addressing the risk of post-default fire sales may not address the risk of pre-default fire sales either. For example, imposing a prolonged stay on repo securities could address the risk of post-default fire sales, as investors would no longer have the option to sell their collateral soon after the default of their counterparty. However, these investors would still have an incentive to run on a troubled dealer. Indeed, these incentives might increase, particularly for investors who are likely to have short-term liquidity needs that could not be met by any of the collateral tied up in the bankruptcy process.

The orderly liquidation authority from Title II of the Dodd-Frank Act also illustrates how addressing the risk of post-default fire sales may not address the risk of pre-default fire sales. This

authority allows the FDIC to transfer all the assets of a failing systemically important institution, including potentially a broker-dealer, to a bridge institution. Should the FDIC transfer all repo contracts to that institution, post-default fire sales would be avoided. However, market participants may be uncertain as to whether and when Title II would be invoked and may rationally decide to reduce their exposure to a troubled dealer quickly, thereby precipitating pre-default fire sales and/or accelerating a dealer default that would prompt fire sales by the dealer's creditors.

For these reasons, it is important to address the risk of both pre- and post-default fire sales. These two types of risk may require distinct solutions, or there may be options that address both risks simultaneously. For example, a liquidation mechanism to address the risk of post-default fire sales could also address the risk of pre-default fire sales if it provided protection for investors against both credit and liquidity risk. This would be the case in the example we outlined in section V, where dealers pre-commit to purchasing the government and agency securities of a large failed dealer. Other arrangements may have the same properties. Clearly, the cost of any solution that deals with these systemic risks should be borne by market participants.

It is essential that credit risk be borne by market participants and not by taxpayers. As noted above, liquidity may be provided by the official sector, depending on how the liquidation mechanism is structured. An important design aspect of a liquidation mechanism, should it rely on liquidity provided by the official sector, is that it does not create moral hazard.

VII. Conclusion

In considering the range of options to address the issue of fire sales of collateral funded in the tri-party repo market, it is useful to differentiate between pre- and post-default situations since the tools needed to address these risks are different.

In the context of this framework, broker-dealers, by reducing the amount of maturity transformation they perform, can mitigate the risk of pre-default fire sales by a dealer that loses

access to tri-party repo funding. In addition, the Federal Reserve has some existing tools, such as the authority to conduct both regular and emergency lending (subject to significant limits and constraints), which could also be used to mitigate this risk by facilitating an orderly deleveraging process. The effectiveness of the Federal Reserve's emergency tools in addressing the problem of fire sales under certain scenarios is also limited by the uncertainty surrounding the specific circumstances under which these tools might be used.

By contrast, there are currently no established tools in place that mitigate ex ante the risk of post-default fire sales. In today's tri-party repo market, dealers can default for a variety of reasons, and the default of a large dealer could lead to fire sales no matter how the default arises. Hence, an effective regime for risk mitigation must feature a mechanism, or process, to ensure ex ante that the incentives faced by tri-party lenders will not result in fire sales in the aftermath of a dealer default. A solution to this collective-action problem will likely require ex ante cooperation and contractual arrangements among tri-party repo market participants.

While ad hoc solutions, as in the case of LTCM, have avoided disasters in the past, the stress associated with such events suggests the need for ex ante well-established solutions. Moreover, the sheer number of creditors in the tri-party repo market would make any attempt to organize a similar solution to manage the failure of a large dealer extremely difficult in practice.

Several approaches could contribute to reducing the risk of fire sales in the tri-party repo market. The resiliency of dealers could be enhanced by reducing their reliance on short-term funding, or through additional capital and liquidity regulation. The volume of assets, particularly lower quality and less liquid assets, financed in the tri-party market could be reduced as a way to reduce the scope for fire sales. The resiliency of tri-party investors could be strengthened, through steps to reduce their own vulnerabilities to run risk.

While improvement along these dimensions would help to reduce the risk of fire sales, we believe that the risk of post-default fire sales in the tri-party repo market cannot be eliminated altogether absent an ex ante mechanism that provides for the orderly liquidation of tri-party collateral, including by funding such instruments for a period of time and clarifying the incidence of any

losses. Active engagement from financial market participants will likely be essential to designing an effective solution. Our framework suggests some avenues for future work in this area. In particular:

- What is the best way to design a solution to ensure orderly sales across multiple market participants? Does the answer differ for a clearing bank versus a CCP model?
- As noted in this paper, fire sales in the tri-party repo market can spread financial stress to other markets and the institutions in those markets. Given this risk of contagion, can an effective solution be reached by tri-party repo market participants alone, or should the views of participants in other markets and in the broader financial system be represented as well?[47]
- How should the burden of resources needed for loss absorption, such as haircuts, default funds, and other loss-absorbing buffers, be allocated across market participants?
- Can market participants be relied upon to provide the liquidity necessary to facilitate the orderly liquidation of assets, even in a scenario in which funding markets are undergoing severe liquidity stress? If not, are there ways in which central bank liquidity could be provided in a manner that ensures systemic risk costs are borne by market participants and that does not create moral hazard for market participants?

More work is needed by regulators, market participants, central banks with financial stability responsibilities, and researchers to address this important weakness of our financial system. In the absence of a mechanism or process for ensuring that private market participants have proper incentives to engage in orderly liquidations of assets as needed, the official sector will likely have to resort to emergency measures in order to limit the disruptions to the financial system that fire sales would create. But relying on emergency measures increases the risk that the systemic costs of fire sales will be borne disproportionately by the taxpayer.

[47] This is analogous to the distinction between "club" goods and "public" goods.

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Appendix A

This section describes the shortfall calculation for each collateral group:

- Assume the liquidity horizons are as given in Table III.
- Assume that the initial amount of a given collateral type is liquidated equally for each day in the liquidity horizon. For example: Agency debt has a 3-day liquidity horizon. Therefore 1/3 of the market value of collateral held on day 1 is liquidated each day.

1. Daily Volatility (Daily Standard Deviation): Use the 120-day average daily volatility measure. The indexes we use for this calculation are given in Table A1.

Table A1.

Collateral type	Index	Bloomberg code
Treasuries	Bloomberg/EFFAS Bond Indices US Govt 1-3 Yr Trsy	USG1TR Index
Agency debt	Barclays US Aggregate Agency Bond Index	AGZ
Agency MBS	Barclays US Mortgage Backed Securities index	VMBS
Corporates	Dow Jones Corporate Bond HG Return	DJCBT Index
Equities	S&P 500 Index	SPX Index

Since a longer horizon implies a larger volatility, the convention for adjusting a daily volatility measure beyond one day is to use a root-t rule (McAndrews and Wasilew [2005]).

$$Daily\ Standard\ Deviation = Average\ Daily\ Volatility * \sqrt{t}$$

Example: Agencies have a 5-day liquidity horizon and an average daily volatility of 0.44%. The volatility on Day 5 is 0.44%√5 = 0.985%*

2. 99% Confidence Standard Deviation: To consider a 1% event, multiply the Daily Standard Deviation by 2.33 (the z-value for 99% confidence).

$$99\%\ Confidence\ St.Dev. = Daily\ Standard\ Deviation * 2.33$$

3. Daily Liquidation: The percent of total exposure liquidated each day of the liquidation horizon.

$$Daily\ Liquidation\ \% = \frac{1}{T} * 100$$

where T = # of days in liquidation horizon.

4. % Remaining Securities: The percentage exposure not liquidated each day.

$$\%\ Remaining\ Securities = 100\% - Daily\ Liquidation\ \% * T$$

5. Value Liquidated:

$$Value\ Liquidated = Exposure * (1 - 99\% confidence\ stdev) * daily\ liquidation\ \%$$

where Exposure = the market value (with accrued interest) of collateral.

6. Value Remaining:

$$Value\ Remaining = Exposure * \%\ Remaining\ Securities$$

7. Daily Potential Collateral Shortfall:

$$Daily\ Potential\ Collateral\ Shortfall = Exposure * Daily\ Liquidation\% - Value\ Liquidated$$

8. Total Potential Collateral Shortfall:

$$Total\ Potential\ Collateral\ Shortfall = \sum_{n=1}^{T} Daily\ Potential\ Collateral\ Shortfall$$

where T = # of days in liquidation horizon.

9. % Potential Shortfall:

$$\%\ Shortfall = \frac{Total\ Potential\ Collateral\ Shortfall}{Exposure} * 100$$