

Strategic Behavior in the Tri-Party Repo Market

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Repo contracts are a kind of collateralized loan that has become predominant in the United States among large cash investors. There are several types of repo contracts, such as bilateral delivery-versus-payment repos, interdealer repos, and tri-party repos. A significant portion of repo transactions in the United States take the form of tri-party repos, where a third party (a clearing bank) provides collateral management and settlement services to the borrower and the lender. The tri-party segment of the U.S. repo market is the subject of this article.

The tri-party repo market played a significant role during the 2007–2009 global financial crisis. Tri-party repos were, for example, a major source of secured funding for Bear Stearns prior to its demise. In March 2008, repo lenders in general, and tri-party repo counterparties in particular, lost confidence in their ability to recoup loans to Bear Stearns and, hence, refused to renew them, asking instead for immediate repayment (Bernanke 2008). To avoid a failure, the Federal Reserve facilitated the acquisition of Bear Stearns by the bank J.P. Morgan Chase. The withdrawal of tri-party repo funding also played a role in the collapse of Lehman Brothers in September 2008. As a result of the events during the crisis, it is now widely believed that the tri-party repo market is subject to serious vulnerability (see, for example, Dudley [2009]). Attesting to this is the fact that in 2009 the New York Fed asked a group of senior private U.S. bank officials to form a task force “to address the weaknesses” in the

■ I would like to thank Jeff Lacker for many stimulating conversations that motivated me to write this article, Jim Peck for answering my game theory questions patiently, and Borys Grochulski, Bob Hetzel, Andreas Hornstein, Tim Hursey, Todd Keister, Antoine Martin, Ned Prescott, Alex Wolman, and John Walter for comments on an earlier draft. All errors and imprecisions are of course my exclusive responsibility. The views expressed in this article are those of the author and do not necessarily represent the views of the Federal Reserve Bank of Richmond or the Federal Reserve System. E-mail: huberto.ennis@rich.frb.org.

infrastructure of the tri-party repo market (Federal Reserve Bank of New York 2010). A broad set of reforms are currently under way.¹

In this article, we study a simple model of the tri-party repo arrangement that allows us to capture in a parsimonious way some of the strategic interactions that arise in this market. In our analysis, we use standard non-cooperative game theory to uncover the basic mechanisms that can create some of the vulnerabilities commonly attributed to the tri-party repo market. We will show that a change in perceptions can create a sudden coordinated withdrawal of lenders from this market. Also, we will highlight the crucial role that the clearing bank plays in this game of “withdrawing before the rest,” which appears to be a good representation of the situation that was present in the tri-party repo market during the recent financial crisis.

A repo (repurchase agreement) transaction is a sale of an asset that is combined with an agreement to repurchase the asset at a pre-specified price on a later day. Effectively, it is equivalent to a collateralized loan, where the loan is the amount paid for the initial sale and the asset plays the role of collateral. Repayment of the loan takes place at the repurchase time, with the interest rate being implicit in the repurchase price. In a tri-party repo, a third party—the tri-party agent—facilitates the transaction between the two main parties, the lender (a cash investor such as a money market mutual fund) and the borrower (a securities dealer such as the broker-dealer arm of an investment bank). The tri-party agent provides custodial and other services to the lender and efficient collateral assignment and allocation tools to the borrower. Settlement happens entirely in the books of the tri-party agent where both the borrower and the lender have cash and securities accounts. Also, in many cases, the tri-party agent (via the so-called “morning unwind”) extends intraday credit to the borrowers to give them access, during the day, to the securities used as collateral overnight. In the United States, the tri-party agents are the two clearing banks, Bank of New York Mellon and J.P. Morgan Chase.²

The volume of repo transactions in the United States is large. There are no official data covering the entire market but Gorton and Metrick (forthcoming) estimate that its size peaked before the crisis at a level that is in the same order of magnitude as the value of all the assets held by U.S. commercial banks (approximately \$12 trillion). The tri-party repo segment of the market is large as well. The value of securities financed in this way was around \$1.7 trillion at the end of 2011, down from about \$2.8 trillion in early 2008 (Federal

¹ Implementation of the reforms have proven to be more difficult than previously expected. On February 15, 2012, the New York Fed issue a statement indicating that the vulnerabilities in this market still persist.

² In what follows, for the purpose of concreteness, we will always call the lender in the tri-party repo the (cash) investor, and we will call the borrower the (securities) dealer. The tri-party agent will be called the clearing bank, or sometimes just the bank, for short.

Reserve Bank of New York 2010). Furthermore, some large broker dealers, arguably of systemic importance, finance large portions of their portfolios in this market. While U.S. Treasury securities and agency mortgage-backed securities (considered virtually riskless) are the most common class of assets used as collateral in tri-party repos, equities and other fixed income securities are also sometimes used. According to some estimates, at its peak in early 2008, about 30 percent of the assets used as collateral were subject to non-negligible liquidity risk (Federal Reserve Bank of New York 2010).³

The amount of the loan in a repo transaction is often lower than the value of the posted collateral. In other words, the value of the collateral gets discounted and this discount is commonly referred to as a “haircut.” Haircuts are aimed at reducing the exposure of the lending side to liquidation costs in case the borrower defaults (see Gorton and Metrick 2010). In principle, choosing the appropriate haircut would leave the repo transaction free of virtually any repayment risk. This is the case because repo transactions are generally exempt from the automatic stay that applies to debt under the U.S. Bankruptcy Code. This implies that the lender side in a repo transaction can take possession of the collateral immediately upon failure of the borrower.⁴

Data on haircuts for different types of repos is limited. However, the available evidence suggests that the level and sensitivity of haircuts depend on the kind of repo transaction being considered. Gorton and Metrick (2010, forthcoming), for example, study a sample of interdealer repo transactions and show that the average haircut increased significantly during the crisis. This is the manifestation of what they call “the run on repos.” Repos were used to finance portfolios of securities and, as the haircuts increased, the capacity to borrow against those securities decreased. The owners of the securities, then, had to find alternative sources of funding or sell the securities in the market. This deleveraging is tantamount to the liquidation of loans that takes place in traditional bank runs.

In contrast, Copeland, Martin, and Walker (2010) show that collateral haircuts in the tri-party repo market did not appear to adjust in any meaningful way to changes in the riskiness of the borrowers. The infrastructure that made tri-party repos attractive to investors seems to have made it less convenient for them to adjust collateral haircuts on a per-transaction basis. Instead, when the financial conditions of a given dealer deteriorated, cash investors tended to withdraw from dealing with such a dealer (PRC Task Force 2010). Evidence

³ Up-to-date information on the composition of collateral in the tri-party repo market can be found at www.newyorkfed.org/tripartyrepo/.

⁴ The repo exemption from the stay is likely to extend to the case of the failure of a broker dealer, as explained by Copeland, Martin, and Walker (2010, Appendix C). There is an ongoing debate about the appropriateness of granting safe-harbor exemptions from the automatic stay to a broad range of derivative transactions, including repos. See, for example, Roe (2009) and Lubben (2010).

suggests that this behavior was predominant during the events that led to the failure of Lehman Brothers (Copeland, Martin, and Walker 2010). This way of reacting to counterparty credit risk in the tri-party repo market is taken as a premise in this article and plays an important role in the theoretical arguments advanced later. In particular, we will investigate the problems that can arise in the strategic interaction between the main players in this market given that withdrawal from lending (and not adjustments of haircuts) constitutes the typical reaction to a change in perceptions about the viability of the borrowing side in the transaction.

Policymakers believe that a breakdown of the repo market can have systemic consequences. In March 2008, after the collapse of Bear Stearns, the Federal Reserve created the Primary Dealer Credit Facility (PDCF) on the premise that “unusual and exigent” circumstances justified the provision of emergency (collateralized) lending to large securities dealers. The idea behind the PDCF was to provide backup liquidity to dealers to give them time to arrange other sources of funding if repo lenders were to suddenly withdraw from the market. The program was designed as a backstop facility, charging a penalty rate on tri-party repo transactions in which the Fed took the lending side (see Adrian, Burke, and McAndrews 2009). Initially, only high-quality collateral (investment-grade securities) was accepted in the PDCF. At the time of the failure of Lehman Brothers, the Fed expanded collateral acceptability to a broader set of assets and usage of the PDCF soared. We will use our model to illustrate one possible role for a lending facility such as the PDCF. However, a more careful assessment of the suitable policy responses to the type of vulnerabilities highlighted in this article is left for future research.

The article is organized as follows. In the rest of this section, we describe the “morning unwind,” a feature of the tri-party repo market that is crucial for understanding the main strategic interaction explored in this article. In Section 1, we set up a simple model of the tri-party repo market and proceed to study the induced strategic interaction between investors and the clearing bank using standard tools in non-cooperative game theory. In Section 2, we discuss some related issues that pertain to the functioning of the tri-party repo market as presented in this article. Finally, Section 3 concludes.

The Morning Unwind

The maturity of most tri-party repo contracts is overnight, but there are also contracts being arranged for a week, 30 days, and even longer periods of time. A common practice in this market, however, is that the clearing bank “unwinds” all repos, regardless of maturity, at the beginning of each day (at around 8:00 a.m. EST).

The process of unwinding takes place as follows. Overnight, the cash investor has the securities in its account at the clearing bank. As part of an implicit arrangement, early in the morning (before the open of Fedwire

securities at 8:30 a.m. EST), the clearing bank transfers the securities back from the investor's account to the dealer's account, and transfers the corresponding cash to the investor (much like in a cancellation of the repo). To finance the transfer of cash, the clearing bank (normally) extends intraday credit to the dealer. In other words, the investor gets a credit in its cash account at the bank and the dealer gets a debit, which usually results in an intraday overdraft of its cash account.

There are several reasons why it is convenient for investors and dealers to have the repos unwound in the morning. Investors benefit from having their cash available to make various payments and to satisfy withdrawal demands placed by their clients during the day. Dealers benefit from having access to the securities for the purpose of trading. In fact, as a result of the trading activities of dealers, the composition of their portfolio of securities changes during the day. If some of the securities being used as collateral in outstanding repos are sold, then they need to be substituted with new securities. This process of *collateral substitution* is simpler if all the securities are transferred to the dealer's account in the morning and only reallocated back to repo contracts at the end of the day.

With the morning unwind, the tri-party repo contract constitutes a loan based on the combination of two sources of funding: investors covering the night and the clearing bank covering the day. As with the overnight credit provided by investors, the intraday credit provided by the clearing bank is secured by the securities held by the dealer in its account at the bank.⁵ In other words, if the dealer were to fail during the day, after the unwind has occurred, then the clearing bank would get ownership of the securities as a way to cancel the dealer's overdraft. If, instead, the failure of the dealer were to occur during the night, then investors would retain ownership of the securities that served as collateral for the tri-party repo transaction.

The morning unwind, then, to the extent that it is financed with the provision of intraday credit to dealers, exposes the clearing bank to the risk of receiving ownership of a batch of securities upon the failure of one (or more) of those dealers.⁶ This unplanned increase in assets of the clearing bank may create some extra costs associated with balance sheet capacity (capital

⁵The clearing bank has a lien on the dealer's collateral structured as a repo with broad flexibility for collateral substitution. When the dealer sells (delivery versus payment) a security during the day, the cash received as payment cancels out the part of the overdraft that is no longer collateralized because of the sale of the security. When a dealer delivers a security free of payment, the clearing bank is protected by its "right of offset" on all the securities that the dealer has at the clearing bank, including those that were not used in tri-party repo transactions.

⁶The ongoing reorganization of the market intends to reduce the predominance of the automatic "morning unwind" practice. See PRC Task Force (2010) for details. However, in the statement issued on February 15, 2012, the New York Fed said: "the amount of intraday credit provided by clearing banks has not yet been meaningfully reduced, and therefore, the systemic risk associated with this market remains unchanged."

constraints, for example). Furthermore, it is possible that part of the overdraft extended to the dealer by the clearing bank is, in turn, being financed by an intraday overdraft of the clearing bank on its account at the Fed. If the dealer fails and the clearing bank cannot resell the securities by the end of the day, it may incur an overnight overdraft at the Fed, which is much more expensive, or it may need to borrow at the discount window. Aside from being provided at a penalty rate, discount window borrowing may also be associated with a stigma effect that can make such an activity very costly for the clearing bank.⁷ The risk of incurring these costs is likely to be a crucial determinant of the willingness of the clearing bank to unwind the repos every morning. The clearing bank retains the right to refuse to unwind the repos of any particular dealer.

At the end of the day, tri-party repos are “rewound” and cash investors are the party exposed to the risk of failure of the dealer during the night. It is common for cash investors in tri-party repos to accept certain securities that they are not allowed to hold permanently in their portfolios. If the dealer were to fail during the night, then, the cash investor would receive a batch of securities that they would need to sell as soon as possible. Rush sales may result in unfavorable prices (beyond the haircut applied to the collateral), effectively exposing cash investors to financial losses.

It is important to realize here that the reason why the clearing bank is (potentially) exposed to credit risk during the day is not because of the process of unwinding the repos in the morning itself, but because such unwinding is generally financed with intraday credit (an overdraft) extended by the clearing bank to the dealer. If, every morning, the dealer were to have enough cash in its account at the clearing bank, then the unwinding would make the repo essentially a secured debt contract with a half-day maturity. The only exposure in that case would be on the lending side (cash investors) and only to the extent that the haircut on the collateral is not enough to cover any discount associated with selling the assets.

1. A SIMPLE MODEL

The tri-party repo market in the United States is a complex system. There are multiple participants facing diverse situations. Some of them are always there, day after day, and some only participate occasionally. The clearing banks, the main broker dealers, and some of the large cash investors participate every day; one can suspect, then, that implicit relationships and reputation, for example, play a significant role in determining outcomes (Copeland, Martin, and Walker 2010). Dealing with all these different dimensions formally is a challenging

⁷ For recent work on the possibility of stigma at the discount window see Ennis and Weinberg (2010) and Armantier et al. (2011).

task and it may not be the most illuminating approach. Instead, here, we will provide a very simple environment that captures only some of the forces at play in this market and we will use standard non-cooperative game theory to analyze the strategic component associated with such a situation.⁸

The model is very simple. There are two time periods, $t = 1, 2$, and three types of agents, a clearing bank, a securities dealer, and N cash investors. At the beginning of period 1, each cash investor has an endowment of c dollars and the dealer has the opportunity to invest 1 dollar in securities, which will pay $1 + \rho$ at the end of period 2. We allow for ρ to be a random variable and consider the natural case in which ρ has a positive expected value. We also assume that $Nc > 1$.

At the beginning of period 1, cash investors deposit (some of) their cash at the clearing bank. Also at that time, the dealer can request a 1 dollar intraday overdraft at the clearing bank to buy the securities. The clearing bank may or may not agree to grant the dealer's overdraft request.

At the end of period 1, the dealer needs to close the overdraft in its account at the clearing bank. We assume that overnight overdrafts are expensive enough to give the dealer incentives to do this. In order to obtain the cash needed to fund the overdraft position, the dealer arranges tri-party repos with cash investors using the securities as collateral. The interest rate on the repos is taken parametrically and denoted by r .⁹

If the dealer is not able to repo the securities, then it has to sell the securities to pay back as much of the overdraft as possible. We assume that securities sold before the end of period 2 only return a portion of what was invested. In such a situation, then, the dealer gets no return and the clearing bank experiences a loss equal to $y_B > 0$.

If the dealer is able to repo the securities, it closes the overdraft at the bank, and the next morning the bank has to decide whether or not to unwind the repos. If the bank decides not to unwind the repos, then the dealer has no funding for the securities, it fails, and investors take possession of the collateral. We also assume that investors cannot hold the securities and need to sell them at a loss at the beginning of period 2. In such a case, again, the dealer gets no return and investors experience a loss equal to $y_I > 0$. The dealer stops being a customer of the bank at that point and the bank gets no payoff from the transaction.

If the bank agrees to unwind the repos instead, the dealer gets a new daylight overdraft in its bank account and investors get their cash and interest

⁸ See Duffie (2010) for a detailed description of the various activities generally undertaken by broker dealers and the role that the repo market plays in funding those activities.

⁹ In the United States, most tri-party repos are arranged in the morning and settle in the books of the clearing bank late in the afternoon, after the close of Fedwire securities. For the formal representation of the problem, the only relevant aspect is that, each day, new repo funding is arranged only after the morning unwind.

back. At the end of the day, the securities pay off and the revenue is used by the dealer to close the overdraft and pay a fee ϕ to the bank.

Note that the initial overdraft could be thought of as the result of the unwinding of a (set of) pre-existing repo contract(s). In that sense, we could think that our simple framework is able to handle two rounds of unwinding, to the extent that the decision to unwind, in this model, will be exclusively driven by forward-looking considerations. This interpretation of the initial overdraft will be useful when we discuss some of the results.

Since we are assuming that $Nc > 1$, investors' initial endowment would be enough to (fully) fund the investment opportunity of the dealer. The way this funding is channeled from investors to dealers is via the clearing bank. The clearing bank receives an initial deposit $d \leq Nc$ from investors and then grants a daylight overdraft to the dealer. If $d > 1$, then, on the books of the clearing bank, the overdraft (loan) to the dealer is (fully) funded by the deposit of investors. However, if investors do not deposit all of their endowment at the bank and $d < 1$, then initial funding for the dealer could still be available. At the beginning of period 1, the bank obtains daylight credit from the central bank in the amount $1 - d$. Later in the period, when (and if) the dealer secures repo funding from investors, the corresponding cash that closes the negative position of the dealer can be used by the bank to close its negative position with the central bank. In this way, the bank can avoid a more expensive overnight overdraft at the central bank.

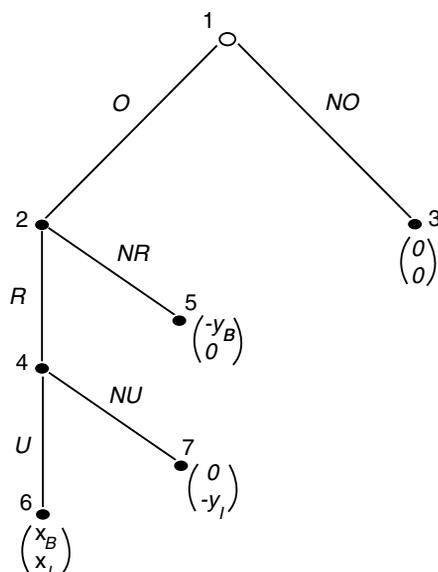
Finally, notice that we have simplified the dealer's side of the problem by assuming that whenever funding is not forthcoming, the dealer fails. This strategy allows us to concentrate our attention on the interaction between investors and the clearing bank.¹⁰ Furthermore, when the dealer fails and the securities need to be liquidated before the end of period 2, the proceeds from the sale are not enough to cover the total value of the loan—the lender suffers losses. In effect, this is a direct counterpart of postulating that insufficient haircuts are applied to the collateral. As discussed in the introduction, the evidence described in Copeland, Martin, and Walker (2010) suggests that this is a reasonable approach to take.

The Non-Cooperative Game

The key strategic interaction in the model is between the clearing bank and the set of investors. To study the outcome from this interaction we can use the tools of non-cooperative game theory. In particular, we will concentrate our attention here on the implied formal game played between the bank and investors.

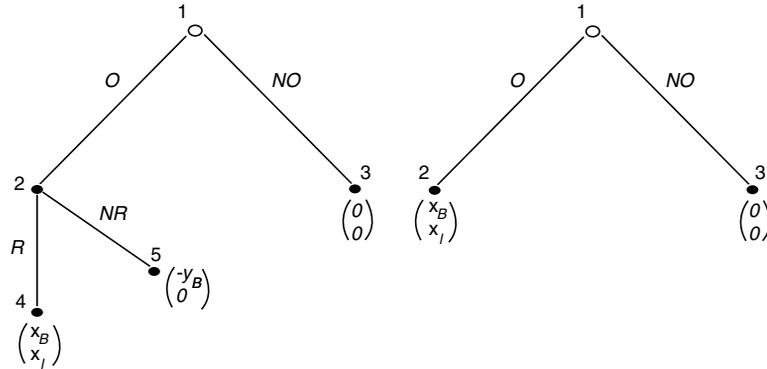
¹⁰ See Martin, Skeie, and von Thadden (2010) for a more fleshed out formal treatment of the role of investors' decisions in determining the fate of the dealer.

Figure 1 The Game with No Uncertainty: Game 1



Let us start with the case when $N = 1$ and $\rho = H \in \mathbb{R}_+$ (i.e., ρ is a given number greater than zero, not a random variable). Assume that $H > \phi + r$. The extensive form representation of this game, which we call Game 1, appears in Figure 1. The game starts in node 1 (represented by an open circle in the figure) with the move by the clearing bank, who has to decide whether to grant the dealer a daylight overdraft (O) or not (NO). After that, if an overdraft is granted, the investor has to decide whether to enter a repo contract with the dealer (R) or not (NR). This is the decision presented in node 2. Finally, if a repo contract is arranged, then the bank has to decide, in node 4, whether to unwind the repo (U) or not (NU) the next morning. In each of the terminal nodes (nodes 3, 5, 6, and 7) the payoffs of the players are listed in a column, with the top element representing the payoff for the clearing bank (the first player to move) and the bottom element representing the payoff of the investor. We use the variables x_i with $i = B, I$ to represent the payoffs to the bank (B) and the investor (I) in the case where an unwinding of the repo happens on the morning of date 2. From our description of the model above, we know that $x_B = \phi$ and $x_I = r$. In a less stylized setup, x_i could be equal to something more complicated, but the basic results from the strategic interaction will be the same as long as the conditions on x_i and y_i established below still hold.

We look for a subgame perfect Nash (SPN) equilibrium of this game. Since Game 1 is a finite game of perfect information, an equilibrium always

Figure 2 Solving for the SPN Equilibrium of Game 1

exists, and, given the payoffs, it is easy to see that the equilibrium is actually unique (see, for example, Osborne and Rubinstein [1994]).

Proposition 1 *There is a unique SPN equilibrium of Game 1 for which the equilibrium actions are (O, R, U).*

Proof. As is standard with dynamic games, we proceed by solving backward. First, consider the decision of the bank in the subgame that starts at node 4, that is, after investors have agreed to repo the securities. If the bank unwinds the repos, then it gets a payoff equal to x_B , which is greater than the payoff of zero obtained from not unwinding. Then, the bank will agree to unwind the repos. We can now write an auxiliary game tree that takes this result into account. This is the tree represented in the left-hand side of Figure 2. Following the same logic, we can now solve backward in this game to find that the investor will agree to repo the securities because $x_B > -y_B$.

Finally, we can draw an auxiliary tree that incorporates this last result (on the right-hand side of Figure 2) and find that the bank will agree to grant an overdraft since $x_B > 0$. Hence, we have that the bank will always play O, then the investor will always play R, and lastly the bank will always play U, which completes the proof of the proposition. ■

When there is no uncertainty with respect to the long-term solvency of the dealer and there is only one cash investor (or a well-coordinated group of them), the dealer always receives funding from the clearing bank (via daylight overdraft) and from the investor (via repo transactions). There is no instability associated with the tri-party repo contract in this case.

Uncertainty over the Dealer's Solvency

Suppose now that ρ is, in fact, a random variable that can take value $H > 1$ with probability ξ and $-L$ with probability $1 - \xi$. We associate the outcome $\rho = -L$ with a situation where the dealer experiences a solvency problem not triggered by the actions of the participants in the tri-party repo market.¹¹ We will consider two cases: one where the game is played without the investor or the bank knowing the realization of the random variable ρ , and the other where the bank gets to know the realization of ρ before deciding whether or not to unwind the repos the morning of date 2.

Uninformed clearing bank

In this first case, both the bank and the investor, when making decisions, share the same degree of uncertainty about the expected performance of the dealer. The structure of the game is almost exactly the same as in Game 1, except that the payoff to the bank in terminal node 6 is now given by $\xi x_B + (1 - \xi)(-f_B)$, where f_B is the loss to the exposed bank when the dealer fails. We call this Game 2a. Note that the payoff to the repo investor in node 6 is still equal to x_I since the unwinding of the repos occurs as in normal circumstances in that branch of the tree. Basically, the idea is that with some probability, the bank finds out that the dealer is insolvent after unwinding the repos and hence is left with a loss equal to $f_B = L + r$ in our model.¹²

Proposition 2 Define $\bar{\xi}_a \equiv f_B / (x_B + f_B)$. If $\xi > \bar{\xi}_a$, then there is a unique SPN equilibrium of Game 2a for which the equilibrium actions are (O, R, U) .

The proof of the proposition follows the same logic as the proof of Proposition 1, so we do not repeat it here. If the probability of the dealer not experiencing a solvency problem is high enough (i.e., if ξ is high enough), then the dealer will get funding from the bank and from the cash investor. However, if the probability ξ is below the threshold value $\bar{\xi}_a$, then the unique SPN equilibrium has the bank playing *NO* in node 1 and the dealer does not obtain funding in such a situation.¹³ We could summarize this result as saying that those dealers who are perceived as “fragile” will not get funded.

¹¹ See Duffie (2010) for a thorough description of the various factors that can contribute to the failure of a dealer bank.

¹² The bank, at the time of unwinding the repos, grants an overdraft to the dealer of size $1 + r$. After the dealer fails, the securities pay $1 - L$ and the bank gets the proceeds. Hence, the net loss for the bank is equal to $L + r$.

¹³ Recall that in game theory, an equilibrium is a property of a profile of strategies. A strategy is a complete contingent plan of play for all possible circumstances in the game, not just the ones that occur in equilibrium. For example, when $\xi < \bar{\xi}_a$, the equilibrium strategy of the bank is $\{NO, NU$ if the investor plays $R\}$ and the equilibrium strategy of the investor is $\{NR$ if the bank plays $O\}$. In this article, we sometimes loosely describe equilibrium play by the actions taken in equilibrium, just to keep the presentation simple.

It is interesting to note that the bank plays *NO* when $\xi < \bar{\xi}_a$ because it anticipates that the investor will not be willing to enter into a repo agreement at the end of the day to finance the dealer. The investor, in turn, does not agree to participate in the repo because it anticipates that the bank will not be willing to unwind the repos the next morning if the repos were outstanding.¹⁴ This anticipation game makes the tri-party repo market very sensitive to changes in perceptions, not just about actual weaknesses of the dealer being funded, but also about the perceptions of other players about those weaknesses.

If we interpret the initial overdraft as (possibly) the result of an unwinding of previously arranged repos, then the model says that if the clearing bank places a high probability on the eventual failure of the dealer *the next day*, the refusal to unwind will take place immediately. This result suggests that the situation can potentially unravel long before the actual failure of the dealer is expected to occur, even if such failure is only regarded as a possibility (and not a certainty).

A crucial issue left unexplored here is how the perception of the probability of failure gets determined and how it changes over time. What the theory here makes clear is that, once such probability has crossed a certain threshold, the whole tri-party repo arrangement is bound to immediately collapse.

Informed clearing bank

The second case we would like to consider in this section is the case when the bank gets to know the realization of ρ before deciding whether or not to unwind the repos on the morning of date 2. We refer to this game as Game 2b. The extensive form representation of this game is provided in Figure 3 where nature moves at node 4. We denote by *NF* the situation when the realized state of nature is such that $\rho = H$, and by *F* the situation when $\rho = -L$.¹⁵ The other new piece of notation in Figure 3 is the payoff f_I , which is the loss experienced by the repo investor when the repo is not unwound by the bank and $\rho = -L$. In principle, f_I could be different than y_I because the liquidation value of the securities may depend on the state of nature.

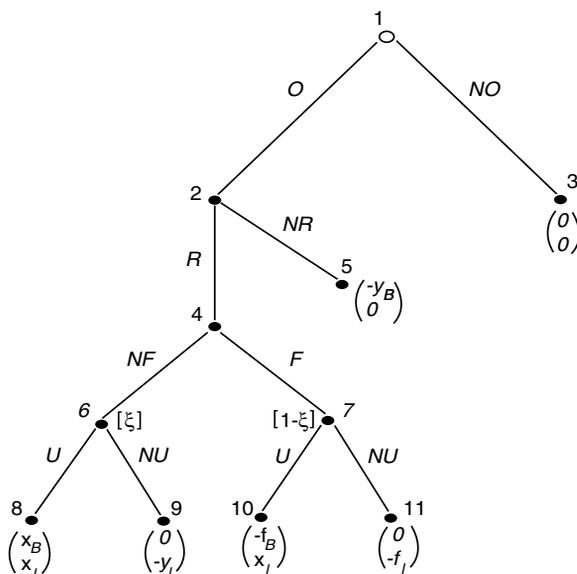
Proposition 3 Define $\bar{\xi}_b \equiv f_I / (x_I + f_I)$. If $\xi > \bar{\xi}_b$, then there is a unique SPN equilibrium of Game 2b for which the equilibrium actions are (*O*, *R*, *U* if $\rho = R$, *NU* if $\rho = -L$).

Proof. First note that in the proper subgame that starts at node 6, the bank should agree to unwind the repos, and in the one that starts in node 7, the

¹⁴ Copeland, Martin, and Walker (2010) call this strategic interaction “the hand-off of risk between investors and clearing banks.”

¹⁵ Osborne and Rubinstein (1994, 101) call games with this structure *extensive games with perfect information and chance moves*.

Figure 3 The Game with Uncertainty: Game 2b



bank should not unwind the repos. Now, using backward induction, we can construct the reduced game where nodes 6 and 7 are terminal nodes and the payoffs are the ones associated with nodes 8 and 11 in the full game. Given that nature moves according to the probability ξ , we have that the payoff for the investor from playing R is equal to $\xi x_I + (1 - \xi)(-f_I)$. Also, the payoff for the bank after playing O and given that the investor is playing R is ξx_B . Now, again, using backward induction, we can construct a reduced game with node 4 as a terminal node and the associated payoffs being $\{\xi x_B, \xi x_I + (1 - \xi)(-f_I)\}$. Clearly, if $\xi > \bar{\xi}_b$, the investor wants to play R and, given this, the bank wants to play O (since $\xi x_B > 0$). ■

If $\xi < \bar{\xi}_b$, the investor will want to play NR when node 2 is reached and, anticipating this, the bank will want to play NO . Thus, if $\xi < \bar{\xi}_b$, the dealer will not obtain the initial overdraft funding from the bank and no repo will be ultimately arranged.

The logic behind these results is clear. The cash investor anticipates that the bank will be able to infer somehow, before the unwinding of the repos, the future performance of the dealer. If the investor believes that it is very likely that the bank will find out that the dealer is bound to fail (and hence that the bank will not unwind the repos), then the investor will not be willing to agree to the repo transaction. In turn, anticipating this, the bank will not

grant an initial overdraft to the dealer and the whole tri-party repo arrangement collapses.

Here, again, we can loosely interpret the initial overdraft as the result of unwinding previously arranged tri-party repos. In this informal interpretation, the crucial element for such a story to work is that there must have been a change in perceptions about the situation of the dealer after repo contracts were arranged prior to the beginning of Game 2b. In particular, right at the beginning of Game 2b, it must be the case that all the participants in the tri-party repo arrangement realized that the dealer actually has a probability of success (the next day) smaller than the threshold $\bar{\xi}_b$ and that the bank will be able to find out whether or not the dealer will fail before the unwinding takes place the following day. If this is the case, then the tri-party repo arrangement *immediately* collapses, not at the time when the failure of the dealer is expected to occur but when the perceptions about that failure actually change (which could very well be much sooner, as the game illustrates).

Discussion

It is interesting to compare the results in Propositions 2 and 3. Note that the thresholds are increasing in the size of the loss if the dealer fails, and they are decreasing in the size of the gain if funding is granted and the dealer does not fail. This is true for both thresholds, although in Proposition 2 the relevant payoffs are those of the bank and in Proposition 3, those of the cash investor. The reason for this difference is the fact that in Game 2a the bank is playing the role of creditor at the time when the dealer fails, while in the case of Game 2b the bank finds out whether or not the dealer will fail before unwinding the repos, and if the dealer is actually expected to fail, then investors will be the party exposed to losses.

This difference in the threshold values has implications for the relationship between fragility and information flows in the tri-party repo market. We can interpret a situation with a lower threshold value as a situation where the tri-party repo arrangement is more likely to survive shifts in participants' perceptions. The idea is that the creditor will accept to stay in the transaction even after larger increases in the perceived probability of failure $1 - \xi$ when the threshold value is lower. Then, if we think that cash investors have less to gain from the repo contract and more to lose relative to the bank—so that the threshold $\bar{\xi}_b > \bar{\xi}_a$ —a situation where everybody anticipates that the bank will be able to obtain information about the solvency conditions of the dealer before the morning unwind (as in Proposition 3) would result in a more fragile tri-party repo market. In such a situation, it is worth noticing, increasing the haircuts applied to the collateral will tend to reduce the loss f_l , reduce the threshold value $\bar{\xi}_b$, and, in this way, improve the stability of the repo market.

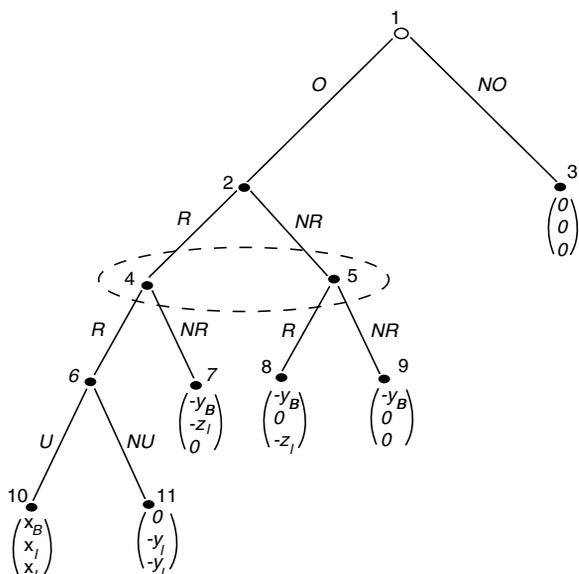
In the simple formal game we have studied in this section, the initial perceptions about the probability ξ are shared by all participants and are correct

in the sense of being equal to the actual objective probability associated with the random variable ρ . This stark information structure hides the fact that the crucial driver of behavior in this strategic situation is the perception that the bank has about the perception of investors about the probability of failure of the dealer. Notice that, in fact, the bank would be willing to grant the initial overdraft to the dealer regardless of the bank's perception of the probability ξ , as long as the bank expects that investors will be willing to repo the securities later in the day. Whether or not investors will be willing to repo the securities depends only on the perception that those investors (and not the bank) have about ξ . So, if the bank thinks that investors are optimistic about the dealer, then, even if the bank is not, the bank will be willing to grant the initial overdraft. This is the case because the bank will get to know whether or not the dealer will fail before unwinding the repos in the morning of the second date and, hence, can effectively get out of the deal without experiencing any losses.

We have considered here the case of only one cash investor with no interim information. However, it would be more realistic to have many investors, each getting some partial information about the solvency condition of the dealer. Because the clearing bank observes the actions of investors in the tri-party repo market, it has a vantage point to aggregate all the dispersed information available to investors and hence, to some degree, anticipate the potential failure of the particular dealer. In other words, after the round of repos during the day, the bank is likely to become better informed about the situation of the dealer. The structure of Game 2b attempts to capture the gist of this situation by having the bank become *perfectly* informed before deciding whether or not to undertake the morning unwind.

Having more than one investor makes the game more complicated and can produce other interesting insights. In particular, the issue of coordination among multiple investors is key to understanding the sources of possible fragility in the tri-party repo market. We discuss some of those issues in the following sections. The analysis in this section applies to a situation where investors can (somehow) perfectly coordinate their actions and play R whenever such a move benefits all of them.

Before we move on to discuss potential coordination issues, it is worth mentioning an interesting implication coming out of the structure of Game 2b. In situations such as the one captured by the timing in that game, any measure aimed at reducing the potential losses of a clearing bank will not change the resiliency of the tri-party repo market. If the clearing bank (by obtaining independent information or by inferring information from the behavior of investors) can (fully) anticipate the failure of any particular dealer before the morning unwind, then the bank is effectively not exposed to actual losses (i.e., the value of f_B is irrelevant for equilibrium, as long as it is positive).

Figure 4 Coordination in the Repo Market: Game 3

Hence, any attempt at reducing a clearing bank's potential losses will not have a material effect on the behavior of the market.

Coordination in the Repo Market

Suppose that there are $N = 2$ cash investors and that, at the beginning of date 2, these investors play a simultaneous move game to decide whether or not to agree to enter repo contracts with the dealer. Also assume that if only one of the two investors agrees to a repo, then the dealer stops operations and the investor that entered the repo agreement experiences a loss equal to z_I . The extensive form representation of this game, which we call Game 3, is given in Figure 4.¹⁶

The encircled decision nodes 4 and 5 constitute a single information set for the investor moving in those nodes. This is the result of the fact that investors play simultaneously and, hence, each investor does not know if the other investor has played R or NR at the time that he has to decide what to play (that is, the investor does not know if he is in node 4 or in node 5, respectively). As before, we look for a SPN equilibrium of Game 3.

¹⁶ Osborne and Rubinstein (1994, 102) call games with this structure *extensive games with perfect information and simultaneous moves*.

Figure 5 Normal Form Representation of the Coordination Game in the Repo Market

		Investor 2	
		<i>R</i>	<i>NR</i>
Investor 1	<i>R</i>	(x_I, x_I)	$(-z_I, 0)$
	<i>NR</i>	$(0, -z_I)$	$(0, 0)$

Proposition 4 *There are two pure-strategy SPN equilibria of Game 3; in one the dealer gets funded and in the other it does not.*

Proof. Note that the branch of the game tree that starts at node 6 is indeed a proper subgame of this game. Clearly, if play reaches node 6, then the bank should agree to unwind the repos (i.e., play *U*) at that point. Using backward induction, we can substitute the payoff from node 10 at node 6 and consider the reduced game that results after this first iteration. In this reduced game (and in the complete game), there is one proper subgame that starts at node 2. In fact, this subgame has the structure of a coordination game between investors and has two pure-strategy Nash equilibria: (R, R) and (NR, NR) (Figure 5 depicts the normal-form representation of this coordination game).

As a result of this multiplicity, the full game actually has two pure-strategy SPN equilibria, one where investors play (R, R) if the proper subgame starting at node 2 is reached, and another where investors play (NR, NR) if this subgame is reached. In the first case, when both investors agree to enter repo transactions, the bank will be willing to grant an overdraft (i.e., play *O*) in node 1. The equilibrium actions will then be $(O, \{R, R\}, U)$ and the equilibrium payoffs will be (x_B, x_I, x_I) .

In the other case, when investors play (NR, NR) , we have that the bank will not agree to initially grant the overdraft and the equilibrium payoffs are equal to zero for all players since the dealer does not get funded from the outset. ■

The equilibrium in which the bank does not agree to grant the dealer an overdraft in node 1 captures in a stylized way a source of potential fragility in the tri-party repo market. If the clearing bank expects that, because of what amounts to a coordination failure, cash investors in the afternoon will not be willing to fund the securities dealer via repo transactions, then the bank will not be willing to grant an overdraft to the dealer in the morning. Recall that, for all practical purposes, the overdraft could originate on an initial request

for funding by a dealer or as the result of the unwinding of outstanding repo transactions. In this sense, then, the model underscores the fragility associated with the daily unwinding of repo transactions that are financed with daylight overdrafts on the accounts that securities dealers have at their clearing banks.

Note here that all agents in the model prefer that the equilibrium in which the dealer gets funded be played at all times. However, because of the possibility of a coordination failure among investors, it is consistent with rational play and equilibrium that the dealer not be funded. Martin, Skeie, and von Thadden (2010) call such a situation a repo run. One way to deal with this problem would be to have the central bank provide backstop liquidity in the repo market, as the Federal Reserve did with the PDCF. In such a situation, investors would get payoff x_i from choosing R , independent of what the other investor is choosing. This change in the structure of payoffs makes (R, R) the unique equilibrium of the game, and the dealer always gets funded. The key to this result is that the policy intervention changes the game among investors so that it is no longer a coordination game.¹⁷ Interestingly, in the model, the PDCF would not be tapped by investors in equilibrium, even though it is essential for ruling out the possibility of coordination failures and, in this way, stabilizing the market.

Martin, Skeie, and von Thadden (2010) (see, also, Copeland, Martin, and Walker [2010]) consider the game played by investors in the case when there is no “morning unwind.” In the context of their model, they show that the investors’ game is no longer a coordination game and, hence, runs can no longer happen. Their model is different, yet related to the model presented here. In particular, they consider the case where there are old and new investors playing the game. Then, the result relies on the assumption that, without the unwind, the dealer gets to observe whether or not it will fail before making any payments to existing (old) investors. This removes the incentives of existing investors to run, even if no new investor is willing to fund the dealer. But, when existing investors do not run, the dealer can withstand a run by new investors, which removes the incentives for new investors to run.

One way to obtain a similar result in our setup is by assuming that, barring daylight credit from the clearing bank, the dealer needs to arrange repo funding before making any investments. Also, let us assume that the dealer goes ahead with the investment only if it is able to convince both investors to fund the operation. In this situation, the payoff to an investor that agrees to enter a repo

¹⁷ This role of the PDCF is highlighted by Adrian, Burke, and McAndrews (2009) when they say: “The PDCF has the potential to benefit trading in the repo market beyond the direct injection of funding. The very existence of the facility is a source of reassurance to the primary dealers and their customers.” Dudley (2009) also says that “the PDCF essentially placed the Fed in the role of the tri-party repo investor of last resort thereby significantly reducing the risk to the clearing banks that they might be stuck with the collateral. As a consequence, the PDCF reassured end investors that they could safely keep investing. This, in turn, significantly reduced the risk that a dealer would not be able to obtain short-term funding through the tri-party repo system.”

contract, when the other investor does not, is the same as the payoff from not entering a repo contract; i.e., it is equal to zero. Assuming, as Martin, Skeie, and von Thadden (2010) do, that in case of indifference an investor agrees to repo, we have that the “unique” equilibrium in the investors’ game is to play (R, R) , and the dealer always gets funded.

Correlated Equilibrium

In the SPN equilibria of Proposition 4, the clearing bank in the morning has no doubts about the events that will take place during the afternoon when the cash investors have to decide whether or not to fund the securities dealer: Either the bank anticipates that funding from cash investors will be broadly available or it anticipates that no investor will be accepting repo requests. In principle, however, the bank may not be sure about the availability of funding in the afternoon. A simple representation of this uncertainty can be accomplished by using the alternative equilibrium concept of *correlated equilibrium*.¹⁸

In particular, suppose that at the time when investors have to decide whether or not to fund the dealer in the afternoon of the first date, they observe a public signal that can take two possible values: α with probability π , and β with probability $1 - \pi$. Suppose also that, when investors observe α , they play the equilibrium with actions (R, R) , and when they observe β , they play the equilibrium with actions (NR, NR) . The bank, instead, does not observe the public signal at the time when it has to decide whether or not to allow the dealer to incur an overdraft on its account at the bank.

Proposition 5 Define $\bar{\pi} \equiv y_B / (x_B + y_B)$. If $\pi \geq \bar{\pi}$, then there is a correlated equilibrium in which the bank plays O in node 1 of Game 3. If $\pi < \bar{\pi}$, then there is a correlated equilibrium in which the bank plays NO in node 1.

The proof of the proposition is very similar to the other proofs and is not included here. We can interpret π as the clearing bank’s perception of the likelihood that the dealer will obtain funding in the afternoon. If the probability is high enough, above the threshold $\bar{\pi}$, then the bank will agree to grant an overdraft. Note that, after the bank allows for the overdraft, with probability $1 - \pi$, investors do not agree to fund the dealer in the afternoon and the clearing bank is stuck with the securities that served as collateral for the overdraft. In such case, the bank suffers a loss given by y_B . Note that, as the loss increases, the threshold value $\bar{\pi}$ increases and gets closer to unity.

¹⁸ There is also a mixed-strategy SPN equilibrium of Game 3 in which investors randomize over actions R and NR , playing R with probability $z_I / (x_I + z_I)$. In such an equilibrium, the bank also faces uncertainty about the ability of the dealer to get funding at the end of period 1. However, we find the interpretation of this equilibrium less appealing and, for this reason, we do not discuss it here.

In other words, as the loss for the clearing bank becomes larger, the bank needs to be more and more certain that investors will fund the dealer in the afternoon if an overdraft is to be granted in the morning. We can think that a lower π represents a situation where confidence in the ability of the dealer to participate in the repo market decreases. If the situation deteriorates enough, to the point when π gets below the threshold $\bar{\pi}$, then the clearing bank will not agree to grant an overdraft (or unwind previously arranged repo transactions by granting the dealer daylight credit).

Note that, in contrast to the situation described in the previous subsection, here the payoff of the bank in case the dealer defaults after the morning unwind is relevant for the outcomes of the game. In the equilibrium of Proposition 5, the clearing bank retains some uncertainty about the ability of the dealer to obtain repo funding in the afternoon of date 1. The key to this result is that the public signal is only observed after the morning unwind and, hence, it creates the potential for a sudden shift in the behavior of investors in the afternoon repo market. Coordination failures are, perhaps, more likely to happen abruptly since they are based only on changes in the beliefs of market participants about the behavior of other market participants. Instead, changes in behavior driven by fundamentals, such as the ones studied in Propositions 2 and 3, are more likely to happen gradually over time, allowing the clearing bank to potentially exploit its informational advantage.

For concreteness, we have considered here a situation with only two investors. However, in general, there could be many more cash investors.¹⁹ An alternative formalization would be to have a continuum of investors deciding at the end of date 1 whether or not to fund the dealer via repo transactions. In such case, it is clear that the decision of any one investor will not have a material consequence on the overall ability of the dealer to fund itself. In other words, if an investor enters a repo contract with a dealer when all the other investors do not, then the dealer will indeed fail and the investor with the repo contract will be stuck with the securities. The structure of payoffs that implies a coordination game arises more naturally in this case, relative to the case where there are only two investors. However, given our assumptions on payoffs, the results would be basically the same in both cases.

2. DISCUSSION

From the perspective of cash investors, the tri-party repo contract is almost equivalent to an interest-bearing demand deposit. Because of the daily unwind, investors have access to their cash during the day (on demand). During the

¹⁹ Copeland, Martin, and Walker (2010) consider a coordination game similar to the one studied here but where there are three investors in the game. See also Martin, Skeie, and von Thadden (2010).

night, the cash is locked in with the repo transaction. The next morning, the contract entitles the investor to a positive interest payment. In an uninsured demand deposit contract, investors are exposed to counterparty credit risk. In contrast, the tri-party repo contract could be considered, in principle, a form of secured lending since there is collateral pledged to address default risk. Haircuts on the collateral could be set so as to leave the lender with virtually no exposure to credit risk. However, in reality, evidence suggests that cash investors still perceive themselves as being exposed to some risk of losses when the borrower defaults (see, for example, Copeland, Martin, and Walker [2010] and PRC Task Force [2010]). We have taken the possibility of losses as a premise for our model, without trying to explain the fundamental reasons for under-collateralization. Understanding how this arrangement could arise optimally is not an easy task. Lacker (2001) provides a framework to think about collateralized debt that could be used to address these kinds of issues (see, also, Dang, Gorton, and Holmström [2010]). More work is clearly needed in this area.

In the United States, paying interest on demand deposits was not allowed until very recently. This restriction was especially binding for businesses. However, the financial system has developed some alternatives that constitute close substitutes of interest-bearing demand deposits. The tri-party repo arrangement could be considered one such alternative. The newly enacted Dodd-Frank financial reform legislation includes a provision that repeals the prohibition of paying interest on demand deposits and, starting on July 21, 2011, banks are now allowed to pay interest on these accounts. It is an open question how this will impact the tri-party repo market in the long run. It seems plausible that some cash investors looking for a way to earn interest on their cash holdings overnight may now turn to demand deposits at banks for this purpose. But, of course, there is a demand as well as a supply side in the tri-party repo market. On the demand side, securities dealers will still need to fund their portfolios of securities. Some form of repo contract is likely to play a role in satisfying that demand.

As we have explained, the source of funding for tri-party repos is two-fold: during the night, cash investors provide the funding and, during the day, daylight overdrafts granted by the clearing banks provide (most of) the funding. Some (if not most) of the cash owned by cash investors does not leave the books of the clearing bank during the day. Those funds are effectively demand deposits held by cash investors in their accounts at the clearing bank. These deposits, then, can be used by the clearing bank to fund the daylight credit provided to the dealers as part of the tri-party repo contract. But, to the extent that some of the cash owned by investors is used during the day to make payments and other transfers, the clearing bank needs to obtain daylight funding for the overdraft granted to the dealers. Of course, one readily available source of daylight funding for clearing banks is their daylight overdraft

capabilities with the Federal Reserve. If we think that the rate charged by the Fed for daylight credit is intentionally kept low (“to ensure the smooth functioning of payment and settlement systems”), then we could conclude that, to a certain extent, the tri-party repo arrangement is an indirect way for dealers to access subsidized funding during the day.²⁰

With its simplified treatment of the events associated with a dealer’s default, our formal analysis could not be used to address some significant issues being discussed in policy circles (see, for example, Copeland et al. [2011]). For example, the possibility that the liquidation of a dealer’s portfolio could result in fire sale prices and externalities to other dealers (and to market participants in general) was left unexplored.²¹ Another important issue that was not examined here is the possibility of “a loss of confidence” in the solvency of a clearing bank. This was a major concern for policymakers during the crisis and has been a salient point in the discussions about possible reforms to the infrastructure in the tri-party repo market (Bernanke 2008). Each clearing bank in the United States provides services to multiple dealers and to a large number of investors. To some extent, dealers need the clearing bank for their daily operation. It seems plausible, then, that problems at a clearing bank could spread to its client dealers if, for example, those dealers were relying on daylight credit to stay in business. Furthermore, cash investors usually have large unsecured exposures to their clearing bank during the day that could also destabilize them if that cash were no longer readily available. These are important issues that deserve careful consideration and are certainly related to the subject of this article. Here, however, we chose to keep the model simple on these dimensions to be able to sharpen our understanding of the strategic interaction between the clearing bank and investors, which may play a crucial role in the functioning of this complex market during a crisis.

In May 2010, the Tri-Party Repo Infrastructure Reform Task Force issued a set of recommendations to increase the stability of this market (PRC Task Force 2010). Their main proposal was to reform the system in order to reduce as much as possible the reliance of market participants on large amounts of intraday credit provided by clearing banks. In short, the proposal calls for an elimination of the indiscriminate daily unwind of all tri-party repo trades. Evidently, reducing the credit exposure of the clearing banks will limit the power of some of the strategic interactions highlighted in this article. However,

²⁰ Currently, the Fed provides daylight credit to depository institutions using a two-tiered fee schedule. Those institutions that pledge enough acceptable collateral with their Reserve Bank receive daylight credit (up to a cap) at no charge. Uncollateralized daylight credit is charged a fee that is calculated per minute using an annual rate of 50 basis points. This system was only recently introduced. During the crisis, the Fed charged a uniform rate of 36 basis points for intraday credit and this credit was all uncollateralized. For more information on the current system see www.federalreserve.gov/paymentsystems/psr_policy.htm.

²¹ For a model that is useful to address some of these issues, see Acharya and Viswanathan (2011).

if the morning unwind creates some valuable operational advantages that make the tri-party repo contract especially attractive to dealers and investors, then an obvious tradeoff arises between stability and effectiveness.²² In such a case, fragility is not to be combated at all costs. As in many other situations where a risk-return frontier results in a tradeoff, the optimal arrangement could very well involve actually tolerating some positive risk.

There are also other alternatives that have been considered to limit this source of fragility in the tri-party repo market. For example, a system of capital requirements and risk charges that penalizes the intraday exposure of the clearing banks may give the appropriate incentives to participants, inducing them to move away from their over-reliance on intraday credit from the clearing banks (Tuckman 2010). Similarly, changes in the treatment of repos under bankruptcy law, such as removing them from the exception to the automatic stay (Roe 2009), could make these contracts less attractive and, hence, reduce the size of this potentially destabilizing market.

As the process of evaluating possible reforms continues, it is important to keep in mind that many of the features of the tri-party repo contract that we observe in the data are contingent on a set of rules (and common practices) that existed when the data was collected. If some of those rules are changed (by fiat or by newly built consensus among major participants), then some prevalent characteristics of the existing contract may also change. A case in point is the distribution of maturity terms in the market. Currently, term trades represent 10 percent to 40 percent of the market (PRC Task Force 2010). To the extent that participants stop perceiving the morning unwind as an automatic event for repos of longer maturities, it seems plausible that an even higher proportion of the outstanding repos will become overnight contracts. This may seem a fairly obvious point, yet it clearly highlights the limitations of evaluating the effects of possible changes in policies using only historical data. To complement our data analysis, we need to develop better models of the tri-party repo market that can allow us to conduct policy evaluations in a more meaningful way. The alternative is a costly process of trial and error purely based on experience in the actual market. Considering the current importance of this market, pushing forward a model-based agenda for studying this market seems worthwhile. The model introduced in this article is an attempt to take a preliminary step in this direction.

²² For example, changing to a system in which repos get unwound only later in the day (or, not unwound at all, in the case of term repos) will make those contracts less comparable with a demand deposit from the perspective of cash investors. While it is true that during the day investors are unlikely to need all the cash used in tri-party repos, the option to have that cash available presumably has some value for investors.

3. CONCLUSION

In this article, we study a simple model of the strategic interaction between investors and the clearing bank in the tri-party repo market. In order to be able to apply simple game theory techniques to the problem, we abstract from many important features of this complex market. We mention several of them along the way in the presentation. Clearly, a lot more work is needed to extend the formal analysis in ways that would allow us to evaluate the role, and the relative importance, of those various features left unexplored here.

Perhaps the aspect most clearly highlighted by the model in this article is the role in the inception of a crisis played by participants' anticipation of each others' perceptions and actions. In particular, the model eloquently illustrates how changes in expectations about future events and actions can make a crisis happen abruptly before the fundamental factors behind it visibly manifest themselves. We conclude, then, that swings in perceptions (about fundamentals or about market confidence) can, in principle, trigger sudden crises in the tri-party repo market.

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