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Abstract

This paper presents a three-period model featuring a short-term investor in the over-the-counter bond market. A short-term investor stores cash because of a need to pay cash at some future date. If a short-term investor buys bonds, then a deadline for retrieving cash lowers the resale price of bonds for the investor through bilateral bargaining in the bond market. Ex-ante, this hold-up problem explains the use of a repo by a short-term investor, the existence of a haircut, and the vulnerability of a repo market to counterparty risk. This result holds without any uncertainty about bond returns or asymmetric information.

JEL: G24.
Keywords: Repo; Over-the-counter market; Securities broker-dealer; Short-term investor; Haircut.

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1 Introduction

Many securities primarily trade in an over-the-counter (OTC) market. A notable example of such securities is bonds.[1] The key feature of an OTC market is that the buyer and the seller in each OTC trade set the terms of trade bilaterally. There has been developed a theoretical literature analyzing the effects of this market structure on spot trading, such as Spulber (1996), Rust and Hall (2003), Duffie, Gârleanu, and Pedersen (2005), Miao (2006), Vayanos and Wang (2007), Lagos and Rocheteau (2010), Lagos, Rocheteau and Weill (2011), and Chiu and Koeppl (2011), for example. This literature typically models bilateral transactions using search models and analyzes various aspects of trading and price dynamics, such as liquidity and bid-ask spread, in an OTC spot market.

This paper analyzes another type of transaction in an OTC market—a repo. A repo is one of the primary instruments in the money market. In this transaction, a short-term investor buys long-term bonds with a repurchase agreement in which the seller of the bonds promises to buy back the bonds at a later date. From the seller's point of view, this transaction is akin to a secured loan with the underlying bonds as collateral. A question remains, however, regarding why a short-term investor needs a repurchase agreement when it can simply resell bonds to a third party in a spot market. The answer to this question is not immediately clear, as the bonds traded in the repo market include Treasury securities and agency mortgage-backed securities, for which a secondary market is available. This paper presents a simple model to show that a short-term investor's need for a repo arises from the investor's short investment horizon and bilateral bargaining in an OTC bond market. It is unnecessary to introduce any uncertainty about bond returns or asymmetric information for this result.

The model features a bond seller in need of cash for its investment, and a short-term investor storing cash until a scheduled date for a cash payment. A bond seller, however, cannot take an unsecured loan from a short-term investor due to limited commitment. Thus,

[1] See Harris (2003) and Biais and Green (2007) for institutional details of the bond market.

a bond seller needs to sell its bond to a short-term investor to finance its funding need. There also exists a third investor that can buy a bond from a short-term investor in a later period, so that a chain of spot bond sales—from a bond seller to a short-term investor, and then to a third investor—is possible.

A chain of spot bond sales, however, cannot finance a bond seller's funding need. This result is due to a hold-up problem for a short-term investor in an OTC bond market. If a short-term investor buys a long-term bond, then the investor needs to resell the bond by the time to pay out cash. This time constraint weakens the bargaining position of the investor against the buyer of the investor's bond. As a consequence, the buyer can negotiate down the bond price through bilateral bargaining in an OTC bond market. Ex-ante, this hold-up problem lowers the highest spot bond price that a short-term investor can pay to a bond seller, resulting in no spot transaction between them.

A repo solves this hold-up problem. Given limited commitment, a bond seller cannot commit to a higher repurchase price than the one resulting from ex-post bargaining. Despite this cap on a pledgeable repurchase price, however, a bond seller can lower the initial selling price of its bond—or pay a haircut—to ensure a sufficiently high yield on a repo for a short-term investor. Lowering the initial selling price is viable for a bond seller, because the bond seller can repurchase the bond at a low price later. Thus, a repo allows a bond seller to finance its funding need. If a bond seller can commit to a repurchase price, then it just makes a repo more useful. But a repo works even under limited commitment.

This result explains why a short-term investor is a main user of a repo in practice, as the need for a repo originates from a hold-up problem specific to a short-term investor. A corollary of this result is that a long-term investor who does not have to resell a bond before the maturity can buy a bond in a spot transaction. Thus, the result explains the co-existence of a repo and a spot transaction by a difference in investment horizons among investors.

The model also explains why a repo market is vulnerable to counterparty risk. If a bond seller goes bankrupt, and hence defaults on a repo, then a short-term investor in that repo must resell a bond to a third party without an option to transact with the bankrupt bond seller. This situation weakens the bargaining position of a short-term investor in an OTC bond market, increasing a discount on the resale price of a short-term investor's bond due to the investor's short investment horizon. Ex-ante, higher counterparty risk raises the haircut and the interest rate for a repo, or even causes a collapse of a repo market, through a short-term investor's concern about the liquidation price of its bond.

Just considering a repo as a secured loan is insufficient for the results in this paper. Using a risk-free bond as collateral should protect a borrower from counterparty risk, if the bond market is competitive. Such a result, however, does not hold because the liquidation price of a bond in an OTC market differs according to the characteristics of each seller. This structure of the bond market makes a short-term investor vulnerable to counterparty risk in a repo. It also explains why such a vulnerable investor is a main user of a repo in the first place.

1.1 Related literature

This paper is related to the analysis of a repo market by Dang, Gorton, and Holmström (2011). In their model, a repo is a secured loan, and a lender faces an adverse selection problem when reselling collateral upon a borrower's default. This problem leads to a positive haircut ex-ante.[2] In contrast, asymmetric information plays no role in this paper's result, because there is no uncertainty about bond returns in the model.

This paper also adds to the paper by Martin, Skeie and von Thadden (2010). They analyze the fragility of the U.S. tri-party repo market, which was about to collapse in 2008. They show that a repo market can collapse due to coordination failure among investors if a clearing bank unwinds a repo every day as in the U.S. tri-party repo market. For this result,

[2]Their analysis is linked to Gorton and Metrick (2012), who explain the fragility of the repo market for private-label securities during the recent financial crisis by asymmetric information.

they assume an exogenous bond liquidation cost. In this regard, this paper contributes to the literature by showing an endogenous bond liquidation cost due to a short-term investor's investment horizon and bilateral bargaining in an OTC market. This result holds even if bonds are risk-free. Thus, it is applicable to a market like the tri-party repo market, in which most of underlying bonds are Treasury securities and agency mortgage-backed securities, i.e., government-guaranteed bonds. This paper confirms that the safety of underlying bonds does not preclude the fragility of a repo market.

This paper is related to the paper by Monnet and Narajabad (2011) in that both papers analyze a repo in an OTC market. But this paper's focus is different from their work. Characterizing a repo as an asset rental, Monnet and Narajabad show that investors both buy and rent assets at the same time if they have idiosyncratic shocks to the utility from holding assets. In contrast, this paper explains the co-existence of a repo and a spot transaction by a difference in investment horizons among investors. This paper is also different from their work in analyzing the common cause for the need for a repo and its fragility.

Mills and Reed (2012) also analyze a repo between a borrower and a lender. They consider limited commitment by both parties, including a failure to return collateral by a lender, and derive a repo endogenously in an optimal contracting problem. Fujiki (2014) extends their framework to cross-border trade. This paper is similar to their work in considering limited commitment by all parties in a repo, but different in analyzing the effect of a short-term investor's investment horizon and bilateral bargaining in an OTC market.

Antinolfi et al. (2012) characterize a repo as a secured loan and analyze the general-equilibrium effects of automatic stay on a repo. This paper adds to their work by modeling a repo in an OTC market and analyzing investors' choice between a repo and a spot bond trade in the presence of automatic stay.

From a broader perspective, there exists a theoretical literature on secured loans, such as Kiyotaki and Moore (1997), Geanakoplos (2009), and Brunnermeier and Pedersen (2009).

See Krishnamurthy (2010a) for a survey of this literature. While this literature typically analyzes a competitive loan market, this paper considers limited commitment in an OTC market. This paper shows that a repo is robust in such an environment.

There exist other strands in the literature on a repo. Duffie (1996) presents a model to analyze a special repo rate in a reverse repo between a security lender and a short seller. Vayanos and Weill (2008) analyze the on-the-run premium on Treasury securities by considering reverse repos in a dynamic search model. In contrast to these papers, this paper focuses on a repo for a short-term investor.

Finally, the hold-up problem for a short-term investor in this paper is related to bid-ask spread in the literature on OTC spot trading described above. In this literature, the motive for an asset sale is typically assumed to be some idiosyncratic shock that raises the seller's asset holding cost. Given a search friction that delays the seller's contact with another buyer, such a shock lowers the threat point for the seller in a bilateral transaction with a buyer, resulting in a low bid price. In the context of this result in the literature, the novel finding of this paper is a linkage between the investment horizon and a hold-up problem: even without any shock, a short-term investor endogenously falls into a hold-up problem ex-post if buying a long-term bond. This linkage is crucial to explain why a short-term investor is a main user of a repo in practice.

Related to this result, there exists a literature on analyzing the optimal market mechanism to prevent a hold-up problem. For example, Gehrig (1993) shows that a Bertland competition among dealers through price posting leads to the Walrusian equilibrium price in a search model. Also, Acemoglu and Shimer (1999) show that price posting with directed search prevents hold-up problems for both firms and workers in a labor search model. In contrast to these papers, this paper shows that a repo prevents a hold-up problem without competition through price posting in the bond market.[3]

[3]Maintaining bilateral bargaining is motivated by the fact that even though dealers quote bid and ask prices, the final terms of trade in each transaction must be determined bilaterally between the dealer and

The remainder of this paper is organized as follows. Section 2 briefly summarizes the stylized features of the repo market in practice. Section 3 presents the baseline model with limited commitment. Section 4 introduces counterparty risk into the baseline model. Section 5 considers the case in which a commitment to a repurchase price in a repo is possible. Section 6 analyzes the effect of automatic stay on a repo. Section 7 concludes.

2 Features of the repo market in practice

This section briefly summarizes the empirical features of the repo market that motivate this paper's analysis. Recently, Copeland, Martin, and Walker (2010) analyze data from clearing banks that provide clearing and settlement services for tri-party repos.[4] They report that typically a short-term investor, such as a money market mutual fund (MMF) or a security lender, buys long-term bonds from a securities broker-dealer in the tri-party repo market. They find that most of the bonds traded in the market are Treasury securities, agency mortgage-backed securities, and agency debt. Also, Krishnamurthy, Nagel, and Orlov (2011) construct data on MMFs and security lenders from Securities and Exchange Commission (SEC) filings by MMFs and data gathered by the Risk Management Association. They show that Treasury securities, agency mortgage-backed securities, and agency debt occupy a large share of bonds held by MMFs and securities lenders through repos. These findings indicate that short-term investors need repos to buy government-guaranteed bonds.

Copeland, Martin, and Walker and Krishnamurthy, Nagel, and Orlov also report an around 2% haircut on repos with government-guaranteed bonds in their samples. A haircut is defined as $1 - p/v$ where p denotes the initial selling price of securities in a repo and v denotes the quoted market value of the securities. Thus, a positive haircut implies that a short-term investor entering into a repo pays a lower price for the underlying bonds than the quoted market price of the bonds.

the client, especially when the client has a large trading order. See Harris (2003, Ch.13) for more details.

[4]This market is called "tri-party" because a clearing bank participates into a repo as a third party.

Another feature of the repo market is fragility. Despite the government guarantees on most of the underlying bonds in the U.S. tri-party market, this market was about to collapse during the two-week period before the failure of Bear Stearns on March 14, 2008. In this period, there were increased concerns about collapses of large securities broker-dealers, i.e., the main counterparties for short-term investors in the market.[5] Even though no public data are available for that period because the market is an OTC market, there exists anecdotal evidence of a turmoil. In the Financial Crisis Inquiry Report, the then Federal Reserve Chairman Ben Bernanke provides his account of the turmoil:

> The $2.8 trillion tri-party repo market had "really [begun] to break down," Bernanke said. "As the fear increased," short-term lenders began demanding more collateral, "which was making it more and more difficult for the financial firms to finance themselves and creating more and more liquidity pressure on them. And, it was heading sort of to a black hole." He saw the collapse of Bear Stearns as threatening to freeze the tri-party repo market, leaving the short-term lenders with collateral they would try to "dump on the market. You would have a big crunch in asset prices." (Financial Crisis Inquiry Commission 2010, pp. 290-291.)

Also, Adrian, Burke, and McAndrews (2009) report that haircuts rose significantly across the market during the two-week period before the failure of Bear Stearns.[6] This observation is puzzling given the fact that the investors in the market were protected by safe underlying bonds, such as Treasury securities.

This paper presents a simple model to analyze these features of the repo market. In summary, the features are:

[5] See Krishnamurthy (2010b) for more details.

[6] The monthly data constructed by Krishnamurthy, Nagel, and Orlov (2011) do not show a significant rise in the haircuts on Treasury securities, agency mortgage-backed securities, and agency debt for March 2008. This is because the data are for the end of each month due to the characteristics of SEC filings. Thus, the market turmoil did not last until the end of March 2008. This finding is consistent with the introduction of the Primary Dealer Credit Facility by the Federal Reserve immediately after the failure of Bear Stearns.

1. A short-term investor needs a repo to buy safe bonds;

2. A haircut is positive in a repo held by a short-term investor;

3. An increase in counterparty risk raises a haircut, or even causes a market collapse, in a repo market with safe underlying bonds.

The model explains these features of the repo market by the same cause: the investment horizon of a short-term investor and bilateral bargaining in an OTC bond market. Regarding the second feature in the list, this paper shows a haircut specific to a short-term investor. This result is complementary to the standard explanation for a haircut based on value-at-risk of underlying securities.[7]

Even though the description of the repo market here is based on existing studies of the tri-party repo market, this is just due to data availability. This paper's analysis is general because the model is based only on the basic feature of the repo market, that is, a short-term investor buys bonds through a repo in an OTC market. Thus, the result is applicable to a bilateral repo, if an investor puts cash on it for short-term investment.[8]

3 Baseline model

Time is discrete and indexed by 0, 1, 2. There are three agents, A, B, C. Agent A is endowed with an amount e of cash in period 0 and consumes cash in period 1. Agent B can invest cash into a project in period 0, which returns an amount A (> 1) of cash per invested cash in period 1. Agent C is endowed with an amount e of cash in period 1. Both agents B and C consume cash in period 2. Storage technology is available so that each agent can store cash without appreciation or depreciation between consecutive periods. Each agent maximizes its expected consumption of cash.

[7] See Geanakoplos (2009) and Brunnermeier and Pedersen (2009) for a haircut based on value-at-risk.
[8] See Gorton and Metrick (2012) for more details about the bilateral repo market.

Given $A > 1$, the first-best allocation is for agent B to invest all of agent A's cash into the project in period 0, promising agent A a rate of return higher than, or equal to, that on storage in period 1. The return on the project, however, is not pledgeable; thus agent B cannot take an unsecured loan from agent A.

Instead, agent B is endowed with a bond in period 0. The bond returns an amount R (> 0) of cash in period 2. Any agent can receive the return on the bond. The bond market is an over-the-counter market. Agents A and B can meet in period 0 to bargain over the terms of a bond sale from agent B to A. If agent A buys the bond, then it can meet with agents B and C sequentially to resell the bond in period 1. Agent A can choose which agent to meet first. The outcome of each bilateral meeting is determined by Nash bargaining with agent A's share of bargaining power equal to α ($\in (0, 1)$).

Assume that

$$e > R. \tag{1}$$

Also assume that agent B is endowed with an amount e of cash in period 1. These assumptions simplify the analysis of the model by ensuring that each agent has enough cash to buy a bond in any event.[9] An equilibrium is a subgame perfect Nash equilibrium. See Table 1 for a summary of the baseline model.

3.1 Interpretation of the baseline model

Agent A represents a short-term investor storing cash until a scheduled date for a cash payment in the near future. Agent A's investment horizon is short because it is shorter than the maturity of the bond. The fixed timing of agent A's consumption represents a rigid due date for a payment obligation in practice. Consumption maximization is equivalent to

[9] If agent A buys a bond at a sufficiently low price in period 0, then agent B cannot pay the period-1 bond price shown below without a cash endowment in the period. Incorporating such an off-equilibrium path only complicates the presentation of the equilibrium without a merit.

maximizing the return on cash while storing cash.[10]

The gross rate of return on Agent B's project, A, can be interpreted literally as the gross return on investment for a borrower using a repo, or as the opportunity cost for a securities broker-dealer to finance its bond holdings with its own capital. In the latter interpretation, agent B holds a bond in period 0 as a result of a transaction with a client outside the model.

There are two ways to finance agent B's funding need. One is a chain of spot bond sales from agent A to B and then to C (Figure 1(a)). The other is a spot bond purchase by agent A with a repurchase by B, which is a repo (Figure 1(b)). In the social planner's allocation, they are indifferent: given limited commitment, the social planner can provide agent B with as much cash as an amount R by requiring agent B to submit a bond as collateral in period 0; the social planner can obtain that amount of cash from agent A by passing on the bond; and the social planner can repay an amount R of cash to agent A in period 1 by retrieving the bond from agent A and passing it on to agent B or C in exchange for an amount R of cash. Note that all of these exchanges are incentive-compatible for each agent at each point in time. This paper shows that this indifference result is overturned if agents bargain over the terms of each bond trade bilaterally, as in an OTC market in practice.

Here, a repo takes a form of an implicit contract, as agents can make only limited commitment. Assuming limited commitment for a repo is consistent with the assumption that an unsecured loan is unavailable. It is also in line with the fact that an investor holding a bond through a repo can cause a settlement fail, i.e., a failure to return the bond to its counterparty at the maturity of the repo, in practice. For robustness check, a commitment to a repurchase price will be introduced in Section 5. As will be shown later, it does not alter the main result of the model.

[10] It is not crucial to assume that agent A literally exits from the economy after consumption. The implication of the model would be robust if an infinite-lived investor received a sufficiently severe punishment in terms of utility or wealth for missing a scheduled payment. This paper adopts a three-period model to keep the analysis as simple as possible. This approach is similar to the literature on liquidity insurance, such as Diamond and Dybvig (1983) and Allen and Gale (1998). While the timing of consumption is stochastic in this literature, it is not necessary for this paper's result.

3.2 Bargaining over a bond resale in period 1

Now solve the model backward. Suppose agent A buys a bond in period 0. Because agent A has the same share of bargaining power, α, against the two agents, the bargaining outcome in period 1 is identical whether agent A meets first with agent B or C in the period.

Let us start from the second meeting in period 1. If agent A does not sell its bond in the first meeting in the period, then the bargaining problem for the second meeting is

$$\max_{p_1'}(p_1' - 0)^{\alpha}(R - p_1')^{1-\alpha}, \tag{2}$$

where p_1' is the bond price that agent A receives from its counterparty in the second meeting, and the left and the right parenthesis are the trade surpluses for agent A and the counterparty, respectively. In the left parenthesis, a zero appears as the threat point for agent A, because agent A misses the opportunity of consumption if it keeps holding the bond until period 2.[11] In the right parenthesis is the profit for the counterparty from buying the bond.

The solution for this bargaining problem is[12]

$$p_1' = \alpha R. \tag{3}$$

Given $\alpha \in (0,1)$, $p_1' < R$; thus, the bond price that agent A can receive in the second meeting in period 1 is lower than the return on the bond in period 2. This result is due to a hold-up problem. Agent A must retrieve cash in period 1 because it can consume cash only in that period. The counterparty for agent A can take advantage of this short investment horizon of agent A, negotiating down the bond price that it pays to the agent.

Given (3), the bargaining problem in the first meeting is

$$\max_{p_1}(p_1 - p_1')^{\alpha}(R - p_1)^{1-\alpha}, \tag{4}$$

[11] It is just for simplicity to assume that a short-term investor does not receive any value if it keeps holding a long-term bond. The key feature of the assumption is that the internal value of a long-term bond for a short-term investor in such a case is less than the face value of the bond. The wedge between the internal value and the face value could be due to a cost of missing a scheduled payment, or an opportunity cost to miss a profitable time-sensitive investment opportunity. Such a wedge results in a discount on the resale price of a short-term investor's bond in an OTC market, leading to the need for a repo as shown below.

[12] This solution is feasible as the counterparty has enough cash to pay p_1' under assumption (1).

where p_1 is the bond price that agent A receives from its counterparty in the first meeting, and the left and the right parenthesis are the trade surpluses for agent A and the counterparty, respectively. In the left parenthesis, p_1' is the threat point for agent A, because agent A can move to the second meeting if the first meeting fails.

The solution for the bargaining problem in the first meeting is

$$p_1 = \alpha R + (1-\alpha)p_1' = (2-\alpha)\alpha R. \tag{5}$$

Agent A resells its bond in the first meeting in equilibrium, if buying a bond in period 0. Given $\alpha \in (0,1)$, $p_1 < R$. Thus, agent A suffers a discount on the resale price of its bond in period 1, because agent A's short investment horizon affects p_1 through p_1'.

3.3 Bargaining over a bond sale in period 0

Move back to period 0. In this period, agent B meets with agent A to sell a bond. The bargaining problem for this trade is

$$\max_{d\in\{0,1\},\, p_0} (p_1 - p_0)^{\alpha}[Ap_0 - R + d(R - p_1)]^{1-\alpha}, \tag{6}$$

where: p_0 is the bond price that agent A pays to agent B; and d equals one if agent A commits to meeting first with agent B in period 1, and zero otherwise.[13] In the left parenthesis is the trade surplus for agent A, which is the profit from a bond purchase for the agent, given the resale price of the bond, p_1, in period 1. In the right square bracket is the trade surplus for agent B. In this term, the gross rate of return on agent B's project, A, is multiplied to p_0, as agent B can invest the revenue from a bond sale into the project in period 0. The opportunity cost of a bond sale is R. If agent A buys a bond in period 0 and then meets first with agent B in period 1 (i.e., $d = 1$), then agent B can expect an additional profit, $R - p_1$, from a bond repurchase in period 1.

[13] The result does not change even if agents A and B can choose a mixed strategy (i.e., $d \in [0,1]$), because $d = 1$ is strictly dominant as shown below.

First, consider a chain of spot bond sales from agent A to B and then to C. In this case, agent A meets first with agent C in period 1. Thus, $d = 0$. The total trade surplus for agents A and B with $d = 0$ can be non-negative if and only if

$$p_1 - \frac{R}{A} \geq 0, \tag{7}$$

which is equivalent to

$$A \geq \frac{1}{(2-\alpha)\alpha}, \tag{8}$$

as implied by (5).

If this condition is violated, then agents A and B cannot find an agreeable bond price with $d = 0$. To see why a spot bond trade breaks down, note that agent A can pay only a low bond price in period 0 because of a discount on the resale price of its bond in period 1. If (7) is violated, then agent A cannot pay an enough bond price to compensate for the present discounted value of the bond for agent B (i.e., R/A). Thus, a low resale bond price for agent A due to its short investment horizon prevents a spot bond trade in period 0.

Next, consider the case that agent A commits to meeting first with agent B in period 1, that is, $d = 1$. In this case, the transaction between agents A and B can be interpreted as a repo, because agent B repurchases a bond in period 1 after selling it to agent A in period 0. Agent A's commitment to returning to agent B is credible, because agent A is indifferent about whether to meet first with agent B or C in period 1 ex-post.

The total trade surplus for agents A and B is always higher with $d = 1$ than with $d = 0$:

$$p_1 - \frac{p_1}{A} > p_1 - \frac{R}{A}, \tag{9}$$

as implied by (5) and $\alpha \in (0, 1)$. The left- and the right-hand side are the total trade surpluses with $d = 1$ and with $d = 0$, respectively. Thus, agents A and B prefer a repo (i.e., $d = 1$) to a chain of spot bond sales (i.e., $d = 0$). Moreover, arranging a repo is feasible even if (7) is violated, because the total trade surplus with $d = 1$ on the left-hand side of (9) is always positive, given $A > 1$ and $p_1 > 0$ as implied by (5).

A repo works because agent B can ultimately take back its bond in a repo. In this case, only the ratio between the initial selling price, p_0, and the repurchase price, p_1, of the bond—that is, the yield—matters. Thus, agent B can lower p_0 to offer a sufficiently high yield for agent A to buy the bond, given p_1. Both agents A and B can gain from this trade, as agent B can offer agent A a yield higher than that on storage, 1, but lower than that on agent B's project, A, given $A > 1$.

With $d = 1$, the solution for the bargaining problem, (6), yields

$$p_0 = \left(\frac{\alpha}{A} + 1 - \alpha\right) p_1 = \left(\frac{\alpha}{A} + 1 - \alpha\right) (2 - \alpha)\alpha R. \tag{10}$$

Also, the interest rate for a repo, denoted by r, can be computed as

$$r \equiv \frac{p_1}{p_0} - 1 = \frac{\alpha(A-1)}{\alpha + (1-\alpha)A}. \tag{11}$$

These terms of a repo are determined through bilateral bargaining endogenously.

3.4 Introduction of a long-term investor and an implied repo haircut

It has been shown that the need for a repo by agent A results from the agent's short investment horizon that ends before the maturity of a bond. A corollary of this result is that a long-term investor can buy a bond without a repo, because it does not have to resell a bond before the maturity. Thus, the co-existence of a repo and a spot transaction can be explained by different investment horizons among investors.

To illustrate this result, replace agent A with agent D which consumes cash in period 2 rather than in period 1. The other characteristics of agent D are as same as those of agent A. Thus: agent D meets with agent B to buy a bond in period 0; if agent D buys a bond in period 0, then it holds the bond until period 2; otherwise agent D meets with agent B in period 1 to bargain over a bond purchase again.[14]

[14] Agent D can always meet agents B and C sequentially as in the baseline model. If agent D does not

The bargaining problems between agents B and D in periods 1 and 0 are respectively:

$$\max_{v_1}(R - v_1)^{\alpha}(v_1 - R)^{1-\alpha}, \tag{12}$$

$$\max_{v_0}[R - v_0 - (R - v_1)]^{\alpha}[Av_0 - R - (v_1 - R)]^{1-\alpha}, \tag{13}$$

where v_1 and v_0 are the bond prices that agent D pays to agent B if agent D buys the bond in periods 1 and 0, respectively. In each bargaining problem, the left parenthesis is the trade surplus for agent D and the right one is the trade surplus for agent B. In the right parenthesis of (12), the gross rate of return on agent B's project, A, is not multiplied to v_1 because agent B can invest cash into the project only in period 0. If agent B sells its bond in period 1, then it just stores the revenue from the bond sale, v_1, until period 2.

Agents B and D can have non-negative trade surpluses in both (12) and (13), given $A > 1$. Thus, agent D can buy a bond without a repo in period 0. The solutions for the bargaining problems yield

$$v_1 = R, \tag{14}$$

$$v_0 = \left(\frac{\alpha}{A} + 1 - \alpha\right) R. \tag{15}$$

With (15), it is possible to calculate a repo margin. The definition of a margin is a difference between the quoted spot price and the initial selling price of a bond underlying a repo. Thus, a margin is defined as $v_0 - p_0$. It is straightforward to show that

$$v_0 - p_0 = \left(\frac{\alpha}{A} + 1 - \alpha\right)(1 - \alpha)^2 R, \tag{16}$$

which is positive given $\alpha \in (0, 1)$. A haircut is also positive as it is defined as $1 - p_0/v_0$.

A margin, or a haircut, is necessary to make a repo robust to limited commitment. Because agent B can commit only to a discounted repurchase price, p_1, due to agent A's short investment horizon, agent A requires a reduction in the initial selling price of a bond, p_0, in period 0. This result implies the presence of a haircut specific to a short-term investor.

buy a bond in period 0, then it meets first with agent B in period 1, because there are no gains from trade between agents C and D in any case. If agent D buys a bond in period 0, then there are no gains from trade between agents B and D in period 1 either.

3.5 Underlying friction and market set-up behind the existence of a repo

Before moving to the next section, let us discuss the underlying friction and market set-up behind the existence of a repo. First, if $\alpha = 1$, then the resale price of a bond for agent A in period 1, p_1, equals the face value of the bond, R, as implied by (5). In this case, the total trade surplus for agents A and B is the same between a chain of spot bond sales from agent A to B and then to C (i.e., $d = 0$) and a repo between agents A and B (i.e., $d = 1$). This result can be confirmed by substituting $p_1 = R$ into (9).[15] Thus, the partial bargaining power of agent A is necessary for a hold-up problem in an OTC market and the need for a repo.

Second, if agent C does not exist, then agents A and B automatically enter into a repo if agent A buys a bond in period 0, because agent A can resell the bond only to agent B in period 1. Thus, the distinction between a repo and a chain of spot bond sales becomes meaningful if there exists another counterparty, agent C, which can purchase a bond from agent A in period 1.

Third, if agent B can choose between meetings with a short-term investor (agent A) and a long-term investor (agent D) in period 0, then it prefers a long-term investor because it can obtain a higher bond price, and thus more cash for its project.[16] It is implicitly assumed that agent B cannot choose its counterparty in period 0 due to some random matching process. This feature of the model is consistent with the fact that a securities broker-dealer in practice finances its inventory of a security through a repo until it finds a buyer. This observation implies that a securities broker-dealer prefers to meet with a long-term investor, but cannot always do so. This paper abstracts from modeling a search and matching process formally, focusing on illustrating the underlying reason for a repo in a simple set-up.

[15] The total trade surplus is $p_1 - p_1/A$ with $d = 1$ and $p_1 - R/A$ with $d = 0$.

[16] The trade surplus for agent B in period 0 equals $(A-1)(1-\alpha)(2-\alpha)\alpha R$ in the meeting with agent A, and $(A-1)(1-\alpha)R$ in the meeting with agent D. Given $\alpha \in (0, 1)$, the latter is greater than the former.

4 Counterparty risk and the fragility of a repo market

Now investigate the sensitivity of a repo to counterparty risk. Suppose that agent B goes bankrupt exogenously with probability μ ($\in (0,1)$) at the beginning of period 1. In case of bankruptcy, agent B simply exits from the model. In this case, agent A can meet only with agent C in period 1. The other part of the model remains as same as in the baseline model.

Here, agent A is allowed to resell its bond to agent C immediately if it arranges a repo with agent B in period 0 and then agent B goes bankrupt in period 1. This assumption reflects the exemption of a repo from automatic stay in the current U.S. bankruptcy code. The case without the exemption from automatic stay will be analyzed in Section 6.

With the possibility of agent B's bankruptcy in period 1, the bargaining problem for a bond sale from agent B to A in period 0, (6), is modified to:

$$\max_{d\in\{0,1\},\, p_0} [\mu p_1' + (1-\mu)p_1 - p_0]^{\alpha}\{\mu \cdot 0 + (1-\mu)[Ap_0 - R + d(R - p_1)]\}^{1-\alpha}, \tag{17}$$

where: the left square and the right curly bracket are the trade surpluses for agents A and B, respectively. In the left square bracket, $\mu p_1' + (1-\mu)p_1$ is the expected resale price of a bond for agent A in period 1. With probability μ, agent A can resell its bond only to agent C because of agent B's bankruptcy. In this case, the bargaining problem becomes as same as (2) due to lack of an alternative counterparty for agent A other than agent C. As a result, the resale bond price in period 1 becomes p_1' shown in (3). In the right curly bracket, $\mu \cdot 0$ appears because agent B's consumption is zero in case of bankruptcy, whatever agent B does in period 0.

Given $p_1 < R$ as implied by (5), the total trade surplus for agents A and B is larger with $d = 1$ than with $d = 0$:

$$\mu p_1' + (1-\mu)p_1 - \frac{p_1}{A} > \mu p_1' + (1-\mu)p_1 - \frac{R}{A}, \tag{18}$$

where the left- and the right-hand side are the total trade surpluses with $d = 1$ and $d = 0$, respectively. The bargaining problem, (17), implies that

$$(d,\ p_0) = \left(1,\ \frac{\alpha p_1}{A} + (1-\alpha)[\mu p_1' + (1-\mu)p_1]\right), \tag{19}$$

if and only if the total trade surplus with $d = 1$ on the left-hand side of (18) is non-negative. This condition is equivalent to

$$\mu \leq \frac{(2-\alpha)(A-1)}{(1-\alpha)A}, \tag{20}$$

given (3) and (5). If (20) is violated, agents A and B do not agree on any deal in period 0.

If (20) is satisfied, then the probability of agent B's default, μ, is small enough that agents A and B can arrange a repo in period 0. In this case, the haircut, $1 - p_0/v_0$, and the interest rate, $p_1/p_0 - 1$, for a repo are increasing in μ, because p_0 is decreasing in μ given $p_1' < p_1$. The quoted spot bond price, v_0, is independent of μ, because there are no gains from trade between a long-term investor (i.e., agent D) and agent B in period 1, as implied by (12); thus, the bargaining problem in period 0, (13), and hence v_0, is unchanged even if agent D loses an opportunity to meet with agent B again in period 1 with some probability.

This result implies that higher counterparty risk makes a short-term investor in a repo require more protection from default as well as more interest, because the investor must liquidate a bond at a discounted price, p_1', if its counterparty defaults.

If (20) is not satisfied, agents A and B cannot find an agreeable initial selling price of a bond in a repo because counterparty risk, μ, is too high. In this case, agent A can pay only a low bond price to agent B in period 0, because agent A expects a low liquidation price of the bond, p_1', in case of agent B's bankruptcy in period 1. Agent B, however, cannot accept such a low price for its bond in period 0, because agent B can repurchase the bond in period 1 only at p_1, rather than p_1', when it is non-bankrupt.[17]

[17] Note that the result is not driven by the absolute level of the number of counterparties for agent A. If there were not agent C from the beginning, then agent B would be the only counterparty for agent A. In this case, agent B's repurchase price of the bond in period 1 would be p_1'. Without counterparty risk, however, agent B would be able to lower the initial selling price of its bond sufficiently that agent A buys the bond

In summary, a repo is vulnerable to counterparty risk, because if default occurs, a short-term investor in a repo must resell the underlying bond to a third party while losing the option to transact with the original counterparty. The loss of an opportunity to trade with a counterparty weakens the bargaining position of the investor against the third party buying the bond. As a result, it increases a discount on the resale price of the investor's bond due to the investor's short investment horizon. Ex-ante, sufficiently high counterparty risk makes a repo market collapse through this concern, despite no risk to the fundamentals of the underlying bond.[18]

An implicit assumption behind this result is that agent B is not immediately replaced by a new entrant into the market in case of default. To interpret this assumption, consider agents B and C as major counterparties in the repo market, such as large investment banks, which can act as a counterparty for a short-term investor with a large volume of cash. Agent A represents such a short-term investor. The model assumes that if one of the major counterparties exits from the repo market, then it is difficult to find a replacement right away. This oligopolistic structure of the repo market makes counterparty risk a concern for a short-term investor ex-ante.

in period 0, because agent B would be able to repurchase the bond at p_1'. Thus, the key to the result is a change in the number of counterparties due to agent B's bankruptcy, and a resulting change in the resale price of agent A's bond from p_1 to p_1'.

[18]Given the risk neutrality of agents, the volatility of R does not affect the results. If risk management is introduced into the model, however, then there can be a linkage between the volatility of bond returns and endogenous counterparty risk. Suppose that R is stochastic and realizes in period 2. The volatility of R is updated in period 1; it increases to a certain value with probability p and remains the same as in period 0 otherwise. Assume that agents B and C have some threshold for value-at-risk of their asset holdings, and if an asset violates this threshold, then they do not hold the asset. Now assume that if the volatility of R increases in period 1, then it violates the value-at-risk restriction on agents B and C. In this case, agent B defaults on a repo endogenously, and agent A cannot find any buyer for its bond in period 1. As implied by the result shown in section 6, the possibility of such an event raises the haircut and the interest rate in a repo, or even makes a repo market collapse, in period 0. The formal analysis of this issue, including why investors set a cut-off threshold for value-at-risk rather than pricing the risk, is beyond the scope of this paper and left for future research.

5 Commitment to a repurchase price

In the baseline model, agents determine the terms of a bond trade through ex-post bargaining in each period. This environment is due to limited commitment by all agents. The baseline model shows that a repo is robust to limited commitment, as it still enables a bond trade between agents A and B in period 0.

If agent B can commit to a repurchase price of a bond in period 1, then it just makes a repo more useful for agents A and B. In case of no counterparty risk, the bargaining problem between agents A and B with a commitment to a repurchase price in period 0 is

$$\max_{d\in\{0,1\},\, \tilde{p}_0\leq e,\, \tilde{p}_1\geq p_1} [d\tilde{p}_1 + (1-d)p_1 - \tilde{p}_0]^\alpha [A\tilde{p}_0 - R + d(R-\tilde{p}_1)]^{1-\alpha}, \tag{21}$$

where: $\tilde{p}_0$ is the initial selling price of a bond that agent A pays to agent B in period 0; $\tilde{p}_1$ is the repurchase price of a bond that agent B commits to paying to agent A in period 1; $d = 1$ implies a repo; and $d = 0$ implies a chain of spot bond sales from agents A to B and then to C. The upper bound on $\tilde{p}_0$ is the amount of cash held by agent A in period 0, e. The lower bound for $\tilde{p}_1$ is set to p_1, i.e., the spot bond price that agent C would pay to agent A if agent A met first with agent C in period 1. This constraint is due to an assumption that agent A cannot commit to returning a bond to agent B in period 1 if $\tilde{p}_1$ is lower than p_1. Thus, agent A can still make only limited commitment. This assumption is in line with the existence of settlement fails in practice.

The left and the right square bracket in (21) are the trade surpluses for agents A and B, respectively. Because agents A and B can always set $\tilde{p}_1 = p_1$, the total trade surplus from a repo with a commitment to a repurchase price necessarily dominates the one without a commitment to a repurchase price. Thus:

$$\tilde{p}_1 - \frac{\tilde{p}_1}{A} \geq p_1 - \frac{p_1}{A} > p_1 - \frac{R}{A}, \tag{22}$$

where the last inequality holds due to (5), given $\alpha \in (0,1)$. The left and the middle term are the total trade surpluses from a repo with and without a commitment to a repurchase price, respectively. The right term is the total trade surplus without a repo (i.e., $d = 0$). Hence, if there is no counterparty risk, agents A and B always arrange a repo in period 0 regardless of whether a commitment to a repurchase price is possible or not.[19,20]

A similar result holds even in the presence of counterparty risk. Suppose that agent B goes bankrupt exogenously with probability μ, as assumed in Section 4. In this case, the bargaining problem between agents A and B over the terms of a repo in period 0 is

$$\max_{\tilde{p}_0 \leq e,\, \tilde{p}_1 \geq p_1} [\mu p_1' + (1-\mu)\tilde{p}_1 - \tilde{p}_0]^{\alpha}[\mu \cdot 0 + (1-\mu)(A\tilde{p}_0 - \tilde{p}_1)]^{1-\alpha}, \tag{23}$$

where p_0 and p_1 in (17) are replaced with $\tilde{p}_0$ and $\tilde{p}_1$, respectively. The use of a repo, i.e., $d = 1$, is already substituted into (23), because it is always feasible to set $\tilde{p}_1 = p_1$, so the total trade surplus from a repo (i.e., $d = 1$) is greater than that without a repo (i.e., $d = 0$).

The necessary and sufficient condition for a non-negative total trade surplus from a repo is (20), as in the case without a commitment to a repurchase price. The key reason for this result is the lower bound for $\tilde{p}_1$, $\tilde{p}_1 \geq p_1$, due to limited commitment by agent A. Given this lower bound, agents A and B set $\tilde{p}_1 = p_1$ in period 0 if μ is sufficiently high, because in such a case, agent A has more interest in buying a bond at a low price than in securing a commitment to a high repurchase price. Thus, a commitment to a repurchase price does not add to the total trade surplus from a repo if counterparty risk is too high. As a result, the necessary and sufficient condition for a non-negative total trade surplus from a repo, and hence the range of counterparty risk in which a repo market exist, is unchanged from (20).[21]

[19] The solution for the bargaining problem (21) is

$$(d,\ \tilde{p}_0,\ \tilde{p}_1) = (1,\ e,\ (\alpha A + 1 - \alpha)e).$$

In this case, $\tilde{p}_1$ is set sufficiently high that agent A pays all of its cash endowment in period 0, e, to agent B (i.e., $\tilde{p}_0 = e$). As agent B can earn an amount Ae of cash by investing an amount e of cash in period 0, agent B can pay out $\tilde{p}_1$ in period 1. Agent A can commit to returning to agent B in period 1, because agent C would pay only p_1 for agent A's bond if agent A met first with agent C in period 1.

[20] Given assumption (1), the haircut, $1 - \tilde{p}_0/v_0$, becomes negative. This result holds because agent B is essentially issuing an unsecured loan by committing to repaying more than the market value of a bond used as collateral. A more realistic assumption is to set a cap on $\tilde{p}_1$ due to some agency problem. The baseline model is an example of such an assumption, in which agent B cannot commit to a repurchase price higher than p_1 due to limited commitment.

[21] More formally, if $(1-\mu)A > 1$, then it is optimal to set $\tilde{p}_0 = e$ to maximize the amount of cash invested

6 Effect of automatic stay on a repo

So far, it has been assumed that a repo is exempted from automatic stay, so that agent A can resell its bond to agent C in case of agent B's bankruptcy. This assumption is consistent with the current U.S. bankruptcy code. Currently, there is discussion whether the exemption should be removed or not. This section describes the effect of automatic stay in the model. For simplicity, consider the baseline case that a commitment to a repurchase price is not possible due to limited commitment.

If a repo is subject to automatic stay, then agent A cannot resell its bond to agent C in period 1 if it arranges a repo with agent B in period 0 and then agent B goes bankrupt in period 1.[22] In this case, the bargaining problem between agents A and B in period 0, (17), is modified to:

$$\max_{d\in\{0,1\},\, p_0} \{\mu[d\cdot 0+(1-d)p_1']+(1-\mu)p_1-p_0\}^{\alpha}\{\mu\cdot 0+(1-\mu)[Ap_0-R+d(R-p_1)]\}^{1-\alpha}. \tag{24}$$

In the left curly bracket, p_1' in (17) is replaced with $d\cdot 0+(1-d)p_1'$. This term is the resale price of a bond for agent A in period 1 in case of agent B's bankruptcy. If a repo is arranged (i.e., $d=1$), this term becomes zero because agent A cannot resell its bond to agent C, and thus misses the opportunity of consumption, in case of agent B's bankruptcy. If agent A buys a bond without a repo (i.e., $d=0$), then it can resell the bond to agent C at p_1' when agent B goes bankrupt.

The choice of d depends on the total trade surplus from each type of trade. The conditions for non-negative total trade surpluses from a repo ($d=1$) and from a spot bond trade ($d=0$)

into agent B's project. The optimal value of $\tilde{p}_1$ falls into a range between $(e-\mu p_1')/(1-\mu)$ and Ae, which is not empty given $(1-\mu)A>1$. If $(1-\mu)A=1$, then only the optimal value of $\tilde{p}_0-(1-\mu)\tilde{p}_1$ is uniquely determined. It falls into a range between 0 and $\mu p_1'$, which is non-empty. If $(1-\mu)A<1$, then it is optimal to set $\tilde{p}_1$ as low as possible. Given $\tilde{p}_1=p_1$, the sufficient and necessary condition for a non-negative total trade surplus for agents A and B is as same as (20).

[22] Assume that the court can identify a repo from the terms of a transaction between agents A and B, even if a repo takes a form of an implicit contract. Thus, agents A and B cannot avoid the application of automatic stay on a repo just by writing no explicit contract. This assumption is consistent with the practice that a repo is regarded as a secured loan contract even if it does not take an explicit form of such a contract.

are respectively:

$$(1-\mu)p_1 - \frac{p_1}{A} \geq 0 \quad \left(\Leftrightarrow \quad \mu \leq f(A) \equiv 1 - \frac{1}{A}\right), \tag{25}$$

$$\mu p_1' + (1-\mu)p_1 - \frac{R}{A} \geq 0 \quad \left(\Leftrightarrow \quad \mu \leq g(A) \equiv \frac{2-\alpha}{1-\alpha} - \frac{1}{\alpha(1-\alpha)A}\right), \tag{26}$$

where the equivalent condition in each parenthesis is calculated from (3) and (5). The total trade surplus from a repo dominates that from a spot bond trade if and only if

$$(1-\mu)p_1 - \frac{p_1}{A} \geq \mu p_1' + (1-\mu)p_1 - \frac{R}{A} \quad \left(\Leftrightarrow \ \mu \leq h(A) \equiv \frac{(1-\alpha)^2}{\alpha A}\right). \tag{27}$$

A repo and a spot bond trade are indifferent if (27) holds in equality. Given these conditions, the solution for the bargaining problem, (24), can be written as[23]

$$(d,\ p_0) = \begin{cases} \left(1,\ \dfrac{\alpha p_1}{A} + (1-\alpha)(1-\mu)p_1\right), & \text{if } \mu \leq f(A) \text{ and } \mu \leq h(A), \\ \left(0,\ \dfrac{\alpha R}{A} + (1-\alpha)[\mu p_1' + (1-\mu)p_1]\right), & \text{if } \mu \leq g(A) \text{ and } \mu > h(A). \end{cases} \tag{28}$$

If $\mu > f(A)$ and $\mu > g(A)$, agents A and B do not agree on any deal in period 0.

Figure 2 draws the functions f, g, and h to illustrate the behavior of agents A and B over the parameter space spanned by counterparty risk, μ, and the gross rate of return on agent B's project, A. For comparison purpose, the figure also contains a panel for the case without automatic stay. In the figure, agent A's share of bargaining power, α, is fixed to 0.5. The results described below, however, hold for any value of $\alpha \in (0, 1)$.[24]

Figure 2 indicates two results. First, automatic stay expands the parameter region for no trade. It reduces the trade surplus from a repo, because it prevents agent A from reselling a bond within the agent's investment horizon if agent B defaults on a repo. As a result, agents A and B find no gains from trade in a repo in a wider range of counterparty risk.[25] Also,

[23]Here, without a loss of generality, it is assumed that agents A and B choose a repo if they are indifferent between a repo and a spot bond trade.

[24]For all $A > 1$ and $\alpha \in (0, 1)$, $g' > f' > 0$ and $h' < 0$. Also, $\lim_{A\to 1} f(A) > \lim_{A\to 1} g(A)$. Thus, f, g, and h intersect only once at the same value of A in their domain, $A > 1$. Denoting this value of A by A^*, it is easy to show that $f(A) > 0$ and $f(A) > g(A)$ for $A \in (1, A^*)$ and that $g(A) > f(A) > 0$ for $A > A^*$. These properties of f, g, and h are sufficient for the two results described below as an implication of Figure 2.

[25]To confirm this result analytically, compare (20) and (25).

the comparison between (19) and the first line in (28) imply that even if agents A and B arrange a repo, the cost of automatic stay makes agent A require a lower initial bond price, p_0, than in the case without automatic stay. Thus, automatic stay hampers the funding for agent B through a repo by raising the haircut, $1 - p_0/v_0$, if a repo market remains open.

Second, for a sufficiently high value of A, there is a range of μ in which agents A and B choose a spot bond trade in period 0. This result contrasts with the case without automatic stay, in which a spot bond trade is never chosen. In this parameter region, counterparty risk, μ, is so high that the expected cost of automatic stay makes a repo less attractive than a spot bond trade. Agents A and B still find gains from trade in a spot bond trade, as a high return on agent B's project, A, makes agent B willing to give up its bond to finance its funding need.

In the second case, the spot bond price that agent A pays to agent B in period 0 is higher than the initial selling price of a bond in a repo without automatic stay. Compare p_0 in (19) and the second line in (28) to confirm this result. In a spot bond trade, agent B requires a higher bond price for its bond to compensate for the opportunity cost of giving up its bond for good. Thus, agent B's investment into its project in period 0, and hence aggregate income, increases if automatic stay on a repo induces agents to switch from a repo to a spot bond trade.[26]

In summary, automatic stay on a repo hampers the funding for a bond seller (i.e., agent B) through a repo, because it prevents a short-term investor (i.e., agent A) from liquidating a bond within its investment horizon in case of a bond seller's default. If counterparty risk is high and a bond seller's funding need is strong, then a short-term investor and a bond seller choose a spot bond trade to avoid automatic stay on a repo while keeping financing the bond seller's funding need.

[26]Despite the expansion of aggregate income, the total trade surplus for agents A and B is higher if they can arrange a repo without automatic stay than if they make a spot bond trade. The increased surplus due to higher aggregate income is absorbed by agent C, which can buy a bond from agent A at a discounted price in period 1 in case of a spot bond trade between agents A and B in period 0.

7 Conclusions

This paper presents a simple model featuring a short-term investor in the OTC bond market. The model illustrates that the investment horizon of a short-term investor and bilateral bargaining in an OTC market result in a hold-up problem for a short-term investor in the bond market. The hold-up problem explains the use of a repo by a short-term investor as well as the vulnerability of a repo market to counterparty risk. Also, the co-existence of a repo and a spot transaction is explained by a difference in investment horizons among investors. These results hold without any uncertainty about the return on the underlying bond or asymmetric information.

In this paper, it is taken as given that the bond market is an OTC market. A question remains regarding the optimal market design, such as whether to introduce a centralized bond market. Also, it remains an issue to introduce a repo into a richer model of a bond market. This paper keeps the model as simple as possible to illustrate the underlying reason for the need for a repo and its fragility. The remaining issues are left for future research.

References

[1] Acemoglu, Daron, and Robert Shimer, 1999. Holdups and Efficiency with Search Frictions. *International Economic Review* 40, 827-49.

[2] Adrian, Tobias, Christopher R. Burke, and James J. McAndrews, 2009. The Federal Reserve's Primary Dealer Credit Facility. *Current Issues in Economics and Finance* 15, no. 4 (August). Federal Reserve Bank of New York.

[3] Allen, Franklin, and Douglas Gale, 1998. Optimal Financial Crises. *Journal of Finance* 53, 1245-1284.

[4] Antinolfi, Gaetano, Francesca Carapella, Charles Kahn, Antoine Martin, David Mills, and Ed Nosal, 2012. Repos, Fire Sales, and Bankruptcy Policy. Federal Reserve Bank of Chicago Working Paper 2012-15.

[5] Biais, Bruno, and Richard Green, 2007. The Microstructure of the Bond Market in the 20th Century. IDEI Working Paper 482. University of Toulouse.

[6] Brunnermeier, Markus K., and Lasse H. Pedersen, 2009. Market Liquidity and Funding Liquidity. *Review of Financial Studies* 22, 2201-38.

[7] Chiu, Jonathan, and Thorsten V. Koeppl, 2011. Trading Dynamics with Adverse Selection and Search: Market Freeze, Intervention and Recovery. Bank of Canada Working Paper 2011-30.

[8] Committee on the Global Financial System, 2010. The Role of Margin Requirements and Haircuts in Procyclicality. CGFS Papers No. 36.

[9] Copeland, Adam, Antoine Martin, and Michael Walker, 2010. The Tri-Party Repo Market before the 2010 Reforms. Federal Reserve Bank of New York Staff Report 477.

[10] Dang, Tri Vi, Gary Gorton, and Bengt Holmström, 2011. Haircuts and Repo Chains. Manuscript. Columbia University.

[11] Diamond, Douglas, and Philip Dybvig, 1983. Bank runs, Deposit Insurance, and Liquidity. *Journal of Political Economy* 91, 401-419.

[12] Duffie, Darrell, 1996. Special Repo Rates. *Journal of Finance* 51, 493-526.

[13] Duffie, Darrell, Nicolae Gârleanu, and Lasse H. Pedersen, 2005. Over-the-Counter Markets. *Econometrica* 73, 1815-47.

[14] Financial Crisis Inquiry Commission, 2011. *The Financial Crisis Inquiry Report.* `http://www.gpoaccess.gov/fcic/fcic.pdf`

[15] Fujiki, Hiroshi, 2014. Default Risks and Collateral in the Absence of Commitment in a Two-country Model. Manuscript, Chuo University.

[16] Geanakoplos, John, 2009. The Leverage Cycle, in Daron Acemoglu, Kenneth Rogoff, and Michael Woodford, eds.: *NBER Macroeconomics Annual 2009*. University of Chicago Press.

[17] Gehrig, Thomas. 1993. Intermediation in Search Markets. *Journal of Economics and Management Strategy* 2, 97-120.

[18] Gorton, Gary, and Andrew Metrick, 2012. Securitized Banking and the Run on Repo *Journal of Financial Economics* 104, 425-51.

[19] Harris, Larry, 2003. *Trading and Exchanges: Market Microstructure for Practitioners.* Oxford University Press.

[20] Hart, Oliver, and John Moore. 1994. A Theory of Debt Based on the Inalienability of Human Capital. *Quarterly Journal of Economics* 109, 841-79.

[21] Kiyotaki, Nobuhiro, and John Moore, 1997. Credit Cycles. *Journal of Political Economy* 105, 211-48.

[22] Krishnamurthy, Arvind, 2010a. Amplification Mechanisms in Liquidity Crises. *American Economic Journal: Macroeconomics* 2, 1-30.

[23] Krishnamurthy, Arvind, 2010b. How Debt Markets Have Malfunctioned in the Crisis. *Journal of Economic Perspectives* 24, 3-28.

[24] Krishnamurthy, Arvind, Stefan Nagel, and Dmitry Orlov, 2011. Sizing Up Repo. National Bureau of Economic Research Working Paper 17768.

[25] Lagos, Ricardo, and Guillaume Rocheteau, 2010. Liquidity in Asset Markets with Search Frictions. *Econometrica* 77, 403-26.

[26] Lagos, Ricardo, Guillaume Rocheteau, and Pierre-Olivier Weill, 2011. Crises and Liquidity in Over-the-Counter Markets. *Journal of Economic Theory* 146, 2169-2205.

[27] Martin, Antoine, David Skeie, and Ernst-Ludwig von Thadden, 2010. Repo Runs. Federal Reserve Bank of New York Staff Report 444.

[28] Miao, Jianjun, 2006. A Search Model of Centralized and Decentralized Trade. *Review of Economic Dynamics* 9, 68-92.

[29] Mills, David C. Jr. and Robert R. Reed, 2012. Default Risk and Collateral in the Absence of Commitment. Manuscript. Federal Reserve Board and University of Alabama.

[30] Monnet, Cyril, and Borghan N. Narajabad, 2011. Repurchase Agreements or, Why Rent When You Can Buy? Manuscript. University of Bern and Rice University.

[31] Spulber, Daniel F., 1996. Market Making by Price-Setting Firms. *Review of Economic Studies* 63, 559-80.

[32] Rust, John, and George Hall, 2003. Middlemen versus Market Makers: A Theory of Competitive Exchange. *Journal of Political Economy* 111, 353-403.

[33] Vayanos, Dimitri, and Tan Wang, 2007. Search and Endogenous Concentration of Liquidity in Asset Markets. *Journal of Economic Theory* 136, 66-104.

[34] Vayanos, Dimitri, and Pierre-Olivier Weill, 2008. A Search-Based Theory of the On-the-Run Phenomenon. *Journal of Finance* 63, 1361-98.

Table 1: Summary of the baseline model

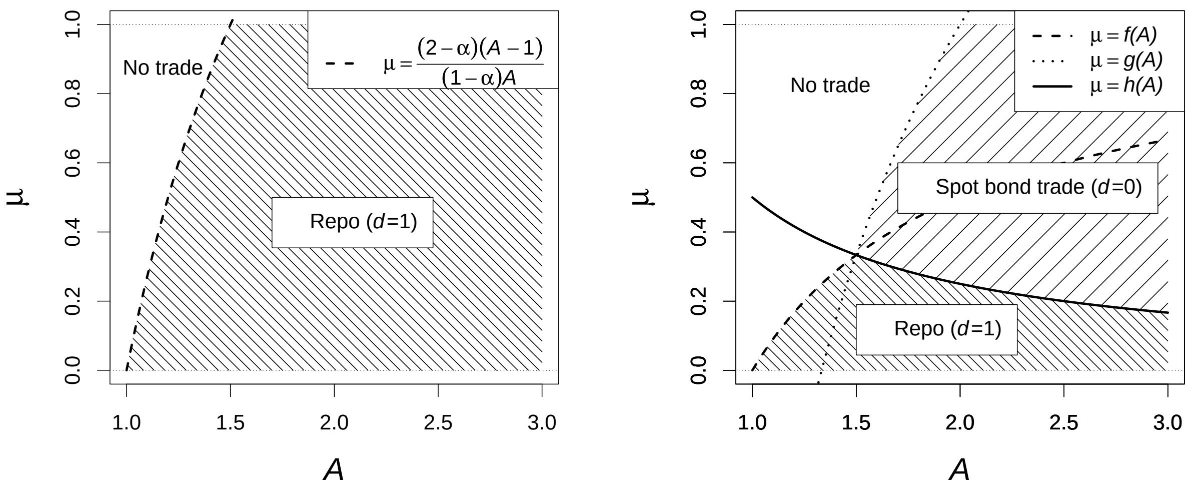
	Period 0	Period 1	Period 2
Agent A	Endowed with an amount e of cash.	Consume cash.	
Agent B	Can invest cash into a project.	The project returns an amount A of cash per invested cash. The return is non-pledgeable. Endowed with an amount e of cash.	Consume cash.
Agent C		Endowed with an amount e of cash.	Consume cash.
Bond	Agent B is endowed with a bond, and meets with agent A to sell the bond.	If holding a bond, agent A can meet agent B and then agent C, or agent C and then agent B, to resell the bond.	The holder of the bond receives an amount R of cash.
	Nash bargaining determines the outcome of each bilateral bond trade. Agent A's bargaining power is α.		
Storage	Each agent can store cash between consecutive periods.		

Figure 1: Two ways to finance agent B's funding need

(a) Chain of spot bond sales

(b) Repo

Figure 2: Type of trade in period 0



(a) Without automatic stay on a repo (b) With automatic stay on a repo

Note: $\alpha = 0.5$. The domain of μ in each panel does not include $\mu = 1$, as it is defined over $\mu \in [0, 1)$. Without automatic stay (panel a), a repo ($d = 1$) is chosen in period 0 if and only if $\mu \leq (2-\alpha)(A-1)/[(1-\alpha)A]$, as shown in (20). Otherwise, there is no agreeable trade in period 0 as a spot bond trade ($d = 0$) never dominates a repo without automatic stay. In the presence of automatic stay (panel b), the definition of the functions f, g, and h is provided by (25)-(27) given the value of α. These functions have the following properties: the total trade surpluses from a repo and from a spot bond trade are non-negative if and only if $\mu \leq f(A)$ and $\mu \leq g(A)$, respectively; a repo dominates a spot bond trade if and only if $\mu < h(A)$; and they are indifferent if and only if $\mu = h(A)$.