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TEACHING FINANCIAL MARKETS STUDENTS ABOUT REPURCHASE AGREEMENTS: THREE EASY LESSONS

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ABSTRACT

Repurchase agreements are critical financing tools that lubricate the financial system. They have been complicit in financial crises, yet they may hold the key to post-recession "normalization." Despite their importance in practice, they are all but ignored in the traditional undergraduate finance curriculum. In this paper, we present a short repo module for financial markets courses. Its three lessons cover both basic and fairly complex quantitative applications, as well as providing an overview of three market disruptions in which repos played a starring role.

JEL: G1, G2, G23

KEYWORDS: Repurchase Agreements, Repos, Financial Crisis, Normalization

INTRODUCTION

Sometimes, what you can't see can hurt you. Financial market participants were reminded of that—the hard way—when the repurchase agreement (repo) market dried up during 2007-8, taking companies like Bear Stearns along with it. Repos lubricate the financial markets; without them, the machine grinds to a halt. Why, then, do finance students learn so little about them?

Repos finance trades in the cash market and thereby facilitate the day-to-day functioning of many financial institutions—they are "the lifeblood of Wall Street." But they are also "murky" (Craig and Spector, 2010). Even Congressional reforms enacted after the financial crisis mostly ignored them, despite their involvement in the market's problems (an oversight that Acharya and Öncü, 2011, deem a "significant mistake"). Their lack of visibility has no doubt contributed to the short shrift they receive in financial textbook coverage. For example, the classic principles text, Brealey, Myers, and Allen (2014), offers only three paragraphs on repos (in its working capital chapter). The practitioner literature is no better. The CFA Institute's 600-page investments book devotes three sentences to repos (McMillan, *et al.*, 2011). Teall (2018) offers one.

Even textbooks devoted to financial markets are stingy on repos. Mishkin and Eakins (2006) include a few paragraphs on the Fed's use of repos, calling them "temporary open-market purchases," then add a few more paragraphs on dealers' use, noting that for them a repo is a "short-term collateralized loan." (These authors do offer a bit of color, mentioning two firms that went bankrupt after using the same securities as collateral for multiple loans.) Kidwell, *et al.* (2006) devote three pages to repos, and include stylized transaction illustrated by T-accounts, as well as a discussion of the calculation of the yield on a repo. (They also add even more detail to the tale of one of those unethical securities firms, noting that one of its principals had two airplanes and gold-plated bathroom fixtures.) And while Madura (2007) mentions repos in multiple chapters, he offers substantive comments only on the same topics as Kidwell, *et al.* (2006), although with less detail.

In this paper, we present a repo module that can be used in a senior-level undergraduate financial markets course. It starts with a silly interactive "play" that introduces students to the players and the motivations behind basic repo transactions. It then describes three historical periods during which repos had a starring role in either market disruptions or recovery: the aftermath of the terrorist attacks of 9/11; the odd negative repo-rate incident of 2003; and the financial crisis of 2007-8. Finally, it details a fairly extensive scenario involving both cash and repo market transactions, which should really stretch students' analytical skills and demonstrate their command of repos. This scenario includes a numerical example using actual market quotes.

The paper proceeds as follows. After describing relevant background literature in the next section, we present the three lessons: the "play," the history, and the scenario. We conclude with a summary and a brief appeal to financial markets professors to give repos the attention they deserve.

BACKGROUND AND LITERATURE REVIEW

As part of the ominously named "shadow banking" system, the repo market allows highly levered nonbanks to lend and invest daily with relatively little government regulation (Acharya and Öncü, 2011). Repo market activity allows dealers to finance their inventories, allows bullish investors to leverage their long positions, and allows bears to short Treasuries. It is also an increasingly critical tool for the Fed's implementation of monetary policy.

Despite the market's importance, the pedagogical literature on repos is essentially nonexistent. There appear to be no articles on Google Scholar devoted to teaching repos; even a general Google search yields no relevant results. This is, perhaps, not surprising, given that even regulators and policymakers had little information on the repo market prior to the 2007-8 crisis, and that the Federal Reserve began a pilot study on bilateral repos only in 2014 (Baklanova, *et al.*, 2016).

There are, however, calls for such a literature: Daniel Tarullo, a member of the Board of Governors of the Federal Reserve System, noted the following in his keynote address to the Conference on the New Pedagogy of Financial Regulation at Columbia Law School in 2016:

> I would urge everyone teaching in this area to place more emphasis on the liability side of the balance sheet of financial institutions…Particularly in the context of systemic risk, funding and liquidity issues…deserve something close to the attention devoted to capital if students are to understand the origins of the [2007-8 financial] crisis, the regulatory response, and the challenges of regulation going forward…An emphasis on runnable funding [like repos] will help them see why systemic concerns extend beyond [systemically important financial institutions].

While there are no pedagogical treatments of repos, there are academic and practitioner articles covering their basics. In this section, we identify several of these articles that will provide students with necessary background. Because there are so many institutional details that may be unfamiliar to students, we break this overview into several subsections, highlighting several key features of the market.

Rate Relationships and Other Basics

There are two articles in particular that provide a thorough introduction to repurchase agreements. The first is Fleming and Garbade (2004). This article covers many fundamental topics: the "immense" size of the repo market; the reasons that dealers would want to short Treasuries (rate increases, hedging, and customer accommodation); how the Fed lends securities from its own portfolio; how dealers handle failures to deliver securities (including their own strategic options to fail on purpose); and how market participants can change standard deal terms to cope with market disruptions (using as their example the "guaranteed-delivery special collateral" repos that were created in 2003).

The second article is Ihrig, *et al.* (2015). One of this article's strengths is its clear explanation of the differences among the various relevant money market rates. While textbooks will usually note that a repurchase agreement is like a collateralized loan, and that the difference between the "sale" price of the collateral and its repurchase price determines the repo rate, students need to be able to put that rate into context. In Ihrig, *et al.* (2015), students learn how the relationships among the rates are driven by policy, how they are affected by collateral, and how they reflect the types of market participants that use them.

In particular, this exposition clarifies the relationships among the key short term rates: the fed funds rate, interest on excess reserves, the primary credit rate (discount rate), and the repo rate. The discount rate is the rate at which institutions can borrow from the Fed. It is usually considered a penalty rate, charged to borrowers who access the Fed as the lender of last resort. We would expect this to be the highest of the four rates. The lowest should be the interest on excess reserves (IOER). The Fed's payment of this rate allows eligible institutions to earn interest on reserve balances above the required amount; institutions that can park unlimited funds at the IOER should not accept a lower rate elsewhere. The combination of the discount rate and the IOER, both set by the Fed, should provide a collar on the fed funds rate, the market-determined rate on loans of reserves among institutions. Finally, the repo rate should be below the fed funds rate, since the former is collateralized while the latter is not.

Although these rate relationships should hold in theory, in practice they may not. The biggest impediment to realizing these rate relationships is the fact that different rates may apply to different financial market participants. For example, government sponsored enterprises (GSEs) cannot earn interest on excess reserves, and may therefore be willing to lend at a rate below the IOER. The current "superabundant" level of reserves in the system—the result of the Fed's extraordinary quantitative easing—is also an impediment. All the reserves sloshing around make it much more difficult for the Fed to raise rates using the traditional scale of its open market operations. The repo market is therefore taking a more prominent place in the Fed's rate-setting toolkit, as we will discuss further below.

Specials Rates

Before students can appreciate how the Fed can use the repo tool, however, they must understand that there is no single repo rate. Since a repo is like a collateralized loan, the desirability of the collateral has an effect on the rate on the loan. Broadly, there are two kinds of collateral: general and special. There are also two motivations for lending in the repo market: finding a short-term parking place for cash, and lending to gain access to a specific security that is pledged as collateral.

If a lender simply wants to deploy cash, she is content to receive as collateral any security from an acceptable class of security (called "general collateral," or GC). General collateral actually may change day to day over the course of a multi-day ("term") repo (Copeland, *et al.*, 2014). Since the lender has no need for specific collateral, she will not accept a rate lower than the GC rate (Fisher, 2002).

However, if a lender's motivation is to acquire ("reverse in") a specific security, then only that security will do, and she will be willing to lend at a lower rate to get it. This lower rate is called a "specials rate," and the desirable collateral is "trading special." Special securities may be hard to get because holders of collateral may be unable (legally) or unwilling (because of transactions costs or portfolio preferences) to supply that collateral to the repo market (Duffie, 1996; Fisher, 2002). There may be as many specials rates as there are types of desirable collateral; in fact, Duffie (1996) calls the degree of specialness "an index of the cost of renting specific collateral."

The potential to borrow at a low specials rate and lend at a higher GC rate can create an arbitrage opportunity. Duffie (1996) exploits this insight to link specials rates, general collateral rates, and the prices for special and GC bonds. He shows that the specials price will exceed the GC price by the present value

of the lower borrowing costs afforded by being able to lend the desirable collateral (which Fisher, 2002, calls the "repo dividend").

Jordan and Jordan (1997) extend Duffie's work empirically. Using a sample of issues trading on special, they find that on-the-run issues (the securities of a particular type that were mostly recently issued) often trade special: 64% of special days in their sample were for on-the-run bonds. The difference between special and GC rates can be material, averaging 123 bp in their early-1990s sample, when the average GC rate was just below 4%. Fisher (2002) provides a stylized timeline of the supply of special collateral, showing that the supply available to the repo market is greatest when the security is issued, but falls over time as more bonds move into the portfolios of non-traders. Supply remains constrained until the new on-the-run security is announced and its when-issued (forward) trading begins. For 13-week securities auctioned quarterly, Fisher estimates that the repo spread increases from zero at issuance to its maximum 11 weeks later, declining thereafter to reach zero at week 13 when the next security is issued.

Not all issues follow this pattern, of course. Jordan and Jordan (1997) describe two prolonged periods of specialness that occurred in the early 1990s, both of which were driven by large dealer short positions in the cash market. In 2003, there was an even more unusual period when specials rates actually went negative. Fleming and Garbade (2004), in explaining this disruption, provide a vivid example of the arbitrage opportunity afforded by low specials rates. (This event is the basis for the second in-class repo lesson, which we cover below.)

The 2003 case illustrates the importance of on-the-run Treasuries. That year, rates on intermediate-term Treasuries had risen significantly mid-year, and market participants long in fixed-income hedged their portfolios by selling short an unusually large amount of the on-the-run Treasuries. Dealers typically take their large positions—and hedge—using the most liquid issues. Somewhat counterintuitively, this then implies that short positions in the most liquid issues are most likely to be "squeezed" (Fisher, 2002). In extreme cases, the Treasury may choose to alleviate a material, ongoing shortage in an issue by actually issuing ore of it; this is called a "reopening." These reopenings may actually serve as a substitute for a new issue, increasing the time the reopened security remains on-the-run (Fisher, 2002). In lesson two, below, we will discuss an unusual reopening that occurred after 9/11.

Tri-party Repos and the Financial Crisis

Not all shortages result from benign market activity. In 2006, several large financial institutions were accused of trying to create a shortage and manipulate the specials rate by borrowing scarce bonds and "parking" them at custodian banks, out of reach from other traders (Ng and Zuckerman, 2006). (At least one Credit Suisse trader and two UBS traders "left their firms" as a result of this incident; Morris, 2006.)

This sort of game happens in the tri-party repo market, where an agent—either JPMorgan Chase or the much more active Bank of New York Mellon—stands between the borrower and lender. These banks manage payments and ensure that the posted collateral meets the lender's requirements, substituting assets if necessary. Tri-party repos are general collateral arrangements, in which the cash lender is simply trying to earn interest. (See Acharya and Öncü, 2011; Fisher, 2002; Hilsenrath and Rappaport, 2012; and Federal Reserve Bank of New York, 2015.)

One service provided by the clearing banks has led to increased regulatory interest in the market since the financial crisis: intraday funding. Traditionally, the banks unwound the prior day's repos every morning, giving cash borrowers access to their collateral securities during the day, in case they needed to deliver them to a counterparty. The repo was then "rewound" in the afternoon, perhaps with different collateral. For the hours between the morning unwind and the afternoon rewind, the clearing bank provided financing to the borrower—concentrating funding, and therefore risk. This risk has been a concern for regulators.

Copeland, *et al.* (2014) studied the performance of the tri-party market during the financial crisis, and found that it was surprisingly stable. Lenders (like money market mutual funds) who faced troubled borrowers (Lehman in particular) simply pulled their funding from the market, rather than changing their rates; this left margins effectively unchanged. These authors conclude that the tri-party market was not a source of general instability during the 2007-8 period, despite problems in the bilateral market. Nonetheless, the potential for problems led the Fed to create a task force on tri-party repo infrastructure reform, and intraday credit has fallen from 100% of tri-party repo volume in 2012 to less than 5% today (Federal Reserve Bank of New York, 2015).

While the tri-party market may have functioned reasonably well during the financial crisis, the repo market was nonetheless intimately involved with some headline failures. If an entity (e.g., Bear Stearns) that relies on daily repo funding suddenly finds itself unable to roll over its repos, it can be forced to sell its portfolio assets at fire-sale prices. (This risk is systematic: since repo financing is secured, it is a market event—not firm-specific credit risk—that shuts a firm out of the market.) Acharya and Öncü (2011) describe such a 2007 "run" among the shadow banks in the repo market, which destroyed some major players (e.g., Bear Stearns), while forcing some to merge (Merrill Lynch) and others to transform into bank holding companies (Morgan Stanley and Goldman Sachs). Ultimately, "the entire Wall Street system of independent broker-dealers collapsed in a matter of seven months" (Acharya and Öncü, 2011).

The Fed's Post-Crisis Use of Repos

Despite complicity in the market collapse, the repo market was critical to Fed's response to the crisis, and is an increasingly important part of the ongoing efforts of "normalization." Ihrig, *et al.* (2015) describe how repos are uniquely suited to normalization, since they are the only one of the Fed's policy tools that can work through all three of its "channels of influence." First, the Fed can use repos to encourage arbitrage, since the rate the Fed sets can act as a floor for other money market rates. Second, repos expand the Fed's sway, because its repo facility is open to counterparties including nonbanks. Finally, the Fed can decrease the amount of reserves on its balance sheet by increasing the size of its repo operations.

Frost, *et al.* (2015) consider in more detail how the Fed has been using reverse repo operations, begun in 2013, to effect normalization, and how those interventions will proceed. As noted earlier, since current reserve balances held by banks are much larger than the normal quantity demanded, the Fed is unable to control the fed funds rate by simply fine-tuning reserves through open market operations. (Prior to the financial crisis, reserve balances were about $15 B, including $2 B of excess reserves; at the end of 2104, there were $2.6 T in reserves, $2.51 T of which were excess. Meanwhile, the Fed's securities holdings more than quintupled; Ihrig, *et al.*, 2015.) Because the reserve balances are expected to remain high for some time, the Fed will not focus its repo activity on draining reserves (its traditional role); instead, reverse repos (through which the Fed borrows from market participants) will be used primarily to help set a floor under money-market rates.

Frost, *et al.* (2015) note that a large Fed reverse repo facility can potentially disrupt markets—perhaps by crowding out private borrowers and exacerbating runs during flights-to-quality—and examine ways to mitigate any negative impact, such as making the facility temporary and setting caps on its use. We will consider the Fed's reverse repo facility in more detail in a later section.

International Issues

While this paper's lessons are concerned solely with the U.S. repo market, the use of repo financing is growing internationally as well. In Europe, for example, "where national barriers persistently inhibit" cross-border clearing and settlement, repos facilitate fast delivery of securities across borders (McGrory, 2014). Armakolla, *et al.* (2017) demonstrate the recent growth of the repo market in Europe, and provide

an overview of the institutions involved. The authors highlight several differences between the U.S. and Eurozone markets that may interest students. For example, the majority of these international repos are cleared through a central clearing counterparty (CCP), an intermediary that guarantees performance on both sides of the trade, and takes collateral from both borrower and lender to ensure it. If the margin collateral involves a different currency than that of the repo collateral, the CCP faces currency risk—a wrinkle students need not consider in the exercises we cover in this paper.

(Note that CCP-cleared repos are distinct from tri-party repos, in which a third party agent provides some back-office services; tri-party repos exist, but are much less common, in the Eurozone. For a detailed explanation of the differences between CCPs and tri-party agents, see McGrory, 2014.)

Eurozone repos can be backed by general or special collateral, as in the U.S., but their sovereign-debt component is much more complicated: since there are multiple countries involved, there are multiple types of sovereign debt, some more creditworthy than others. Thus, as noted by McGrory (2014), the general collateral repo market in Europe is fragmented by country (e.g., there is a French market and a German market, but there is no co-mingled "Eurozone" market). This sort of distinction is also clear from the "haircuts" imposed by CCPs when accepting margin collateral. Armakolla, *et al.* (2017) document significant differences in the desirability, and associated intermediary haircuts, of various countries' debt during the European sovereign debt crisis, when countries like Ireland and Portugal were subjected to severe collateral haircuts, while France and Germany were relatively unaffected. (Armakolla, *et al.*, 2017, also touch on the broader 2008 financial crisis. For an in-depth examination of the different responses by the Fed, the Bank of England, and the European Central Bank to that crisis, which highlights the latter's use of repos, see Pisani-Ferry and Wolff, 2012.)

Finally, regulatory issues will be different in the European market and in the U.S. (See McGrory, 2014, for an overview of current and proposed regulations.) For example, Armakolla, *et al.* (2017) expect that a financial transactions tax will eventually apply to certain types of European repos, which should decrease overall repo volume and completely kill overnight transactions. McGrory, 2014, agrees that such a tax—which could be imposed on both legs of a repo—would destroy the market, but concludes that revisions to the initial proposal make it unlikely now that repos would be included in a final version of any regulation.

Having described the basics of the repo market, we turn now to three lessons that should help students remember them.

FIRST LESSON: A TWO-ACT PLAY

In a senior-level financial markets course, repos can be covered in two, 80-minute class periods. These should happen after the instructor has covered the basic structure of the money market, has introduced the assets that trade there, and has discussed how the Fed's interventions affect the market. With this background in hand, the instructor would use the first repo day to go over repos and reverses using two very simple sets of drawings (like a simplified version of Figure 2, described in lesson three, below). The second day covers the historical applications from lesson two, described in the next section.

The first day's exposition would start with the idea that the dealer (whose perspective the class takes) has an expectation about the path of future T-bond prices. (It is easier to introduce the transactions in terms of prices, since students find it natural to think of buying low and selling high. The price forecast is then translated it into the equivalent rate forecast: rates are expected to fall in the repo case, and rise in the reverse case.) Suppose that the dealer thinks prices will rise. Thus, to make a profit, she wants to "buy low, sell high": buying low first (at t=0), and selling high later (at t=1). She therefore needs to begin by buying a T-bond in the market at t=0.

However, we assume that the dealer starts with nothing. Anything she wants to do in the cash market must be accommodated in the repo market. Thus, she needs to use the repo market to get the money she needs to buy her T-bond. She will be doing a repo, and her counterparty will be doing a reverse. (There is a tremendous amount of terminology in the repo market, and it can be difficult to keep it all straight. One helpful mnemonic is "rep**o** = b**o**rrow." Another is "rep**o** **o**ut; reverse in," where the "out" and "in" refer to what is happening with the collateral—going out from the dealer, or coming in to her.) Thus, at t=0, our dealer gets a loan from her repo counterparty, uses that money to buy a T-bond in the cash market, then hands that T-bond right over to her repo counterparty as collateral for her loan. At the end of t=0, she is again left with nothing (except the obligation to unwind her repo, of course).

At t=1, it is time for the dealer to cash in on her market insight. (We assume that she was right, and that prices will rise.) To complete her "buy low, sell high," it is time to sell high: she will sell at T-bond to a market participant at the new, higher price. She gets the bond by retrieving her collateral from her repo counterparty. She then sells the bond in the cash market, using part of her proceeds to repay her loan to her repo counterparty, and keeping the rest as her profit. Thus, her profit is the change in price of the bond, less the interest on her loan.

The reverse repo illustration proceeds similarly, although it begins with the dealer's expectation that prices will fall (as rates rise). She therefore must sell high first, and buy low later. (The short perspective does not come naturally to many students, and most may not have heard of short selling at all. The instructor may therefore want to briefly describe shorting stocks, taking a short position in futures, using long puts or short calls to express bearish bets, or whatever other positions may help her students appreciate the potential to make money in down markets.) The dealer now accommodates her t=0 sale of a T-bond by reversing in collateral (lending cash against collateral); at t=1, she will buy a bond in the cash market (at a lower price, she hopes), returning that bond to her repo counterparty and getting her loan repaid with interest. In this case, her profit will come not only from the decrease in price, but also from the interest she earns in the repo market.

Once students have gone through these two basic examples, they are ready for two "plays." Each play—repo and reverse—has two scenes: t=0 and t=1. To remind students what time it is, one student can play "Father Time"; this student gets large cards with "t=0" and "t=1" printed on them, which he can hold up to announce the scene. Another student can play "the market"; this student has cards with the prices of T-bonds printed on them (three cards, one each for the two-, three- and four-pen prices). All of the other parts noted below are also played by students (except for the dealer, who is played by the instructor). Each actor gets a card telling her what she wants to do (buy a bond, sell a bond), plus perhaps a prop (a "T-bond" and/or some pens, which is the currency of the realm).

In classrooms whose the desks are arranged in a horseshoe shape, it is easy for the instructor to be in the center of the group and to pass things (pens and bonds) around. (For classrooms arranged more traditionally, with all desks facing forward, having the actors stand can help dramatize the exchanges.) It is more fun when both the instructor and the actors try to be as overly dramatic as possible. Students should enjoy this activity, but instructors should be warned: they will probably respond at the end with something like, "Cool! That worked! Wait, how did that work again?" Thus, instructors should provide diagrams for them to study afterward. (Another possible pitfall: If they are asked later to explain the process on a test, they might respond in terms of pens. Students will probably laugh when reminded that a pens-to-dollars translation is necessary, but it is a good reminder. Lesson three, below, can also help make this translation explicit.) Tables 1 and Table 2 describe the repo and the reverse repo plays, respectively.

Table 1: A One-Act Repo Play

CAST	
Character/Mission	**Endowment**
FATHER TIME	two cards noting times (t=0 and t=1)
THE MARKET	three cards noting prices (2, 3, and 4 pens)
DEALER	nothing
profit when T-bond price rises: buy low, then sell high (borrowing cash to finance a long T-bond position)	
REPO COUNTERPARTY	2 pens
profit on cash loan (e.g., a money market mutual fund)	
INVESTOR #1	T-bond
sell a T-bond at t=0	
INVESTOR #2	4 pens
buy a T-bond at t=1	
SCENE 1: t=0	
Character	**Action**
FATHER TIME	shows "t=0" card
THE MARKET	reveals the price of a T-bond: 2 pens
REPO COUNTERPARTY	gives DEALER 2 pens
DEALER	uses 2 pens to buy T-bond from INVESTOR #1
DEALER	gives T-bond to REPO COUNTERPARTY
SCENE 2: t=1	
Character	**Action**
FATHER TIME	shows "t=1" card
THE MARKET	reveals the price of a T-bond: 4 pens
DEALER	sells T-bond to INVESTOR #2 for 4 pens
DEALER	gives 3 pens to REPO COUNTERPARTY
REPO COUNTERPARTY	gives collateral T-bond back to DEALER
DEALER	gives T-bond to INVESTOR #2

This table outlines the first "play," in which the DEALER enters into a repo transaction. She is borrowing money to finance her long position in T-bonds (she thinks T-bond prices will rise as rates fall). The dealer starts with nothing. At t=0, she borrows money (2 pens) from her REPO COUNTERPARTY, using the 2 pens to buy a T-bond (which she then gives to the REPO COUNTERPARTY as collateral for the loan). At t=1, after prices have risen to 4 pens, she retrieves this collateral bond from the REPO COUNTERPARTY, sells it at the new, higher price, then repays her loan with interest (a total of 3 pens: a 2-pen loan, plus 1 pen in interest). Because the price has risen by more than the interest charge she incurs, she profits by one pen. Note that the transactions are roughly coincident, so students need not worry that the DEALER sells or pledges something she does not (yet) have.

Table 2: Reverse Repo: A One-Act Sequel

CAST	
Character/Mission	**Endowment**
FATHER TIME	two cards noting times (t=0 and t=1)
THE MARKET	three cards noting prices (2, 3, and 4 pens)
DEALER	nothing
profit when T-bond price falls: sell high, then buy low (lending cash as part of a short T-bond position)	
REPO COUNTERPARTY	T-bond and 1 pen
borrow cash using collateral (e.g., a hedge fund)	
INVESTOR #1	3 pens
buy a T-bond at t=0	
INVESTOR #2	T-bond
sell a T-bond at t=1	
SCENE 1: t=0	
Character	**Action**
FATHER TIME	shows "t=0" card
THE MARKET	reveals the price of a T-bond: 3 pens
REPO COUNTERPARTY	gives DEALER a T-bond
DEALER	sells T-bond to INVESTOR #1 for 3 pens
DEALER	gives 3-pen loan to REPO COUNTERPARTY
SCENE 2: t=1	
Character	**Action**
FATHER TIME	shows "t=1" card
THE MARKET	reveals the price of a T-bond: 2 pens
DEALER	buys T-bond from INVESTOR #2 for 2 pens
DEALER	gives T-bond to REPO COUNTERPARTY
REPO COUNTERPARTY	gives 4 pens to DEALER (loan + interest)
DEALER	gives 2 pens to INVESTOR #2

This table illustrates the reverse repo, in which the DEALER manages a short position in T-bonds. She must reverse in a T-bond from her REPO COUNTERPARTY at t=0, using the money she gets from selling it (3 pens) as a loan to the REPO COUNTERPARTY. At t=1, the REPO COUNTERPARTY repays this loan with interest; the DEALER uses this money to buy a T-bond in the market (at the new, lower price), returning the collateral. The DEALER profits from the interest on the loan and on the decline in the bond's market price.

Now that students have this necessary background, they should be ready to apply their knowledge in lesson two.

SECOND LESSON: REPOS THROUGH HISTORY

Studying instances of significant financial market trauma can help students appreciate the integral nature of the repo market. In this section, we describe three such instances: the broad market's flight to quality and consequent dislocation after the 9/11 terrorist attacks; the specials market stress in 2003 that led to negative repo rates; and the great recession in 2007-8 and the Fed's ongoing response.

9/11

The 9/11 attacks destroyed significant amounts of financial market infrastructure in Manhattan, disrupting the (generally ignored) "pipes" that keep the money market functioning. Here, the big lessons for students of the repo market are that repo counterparties can "fail," and that the government can relieve a security shortage by reopening an issue. Fleming and Garbade (2002) describe these effects in detail. However, students may be more engaged if the instructor uses contemporary *Wall Street Journal* articles to motivate the relevant classroom discussion, because it is interesting to watch the Treasury's response as it unfolds across several articles. Specifically, students can get a good overview of events by reading Ip and Zuckerman (2001, from October 5), Zuckerman and Ip (2001; October 8), Downey and Derby (2001; October 10), and Christie (2001; October 11).

A "fail" is simply a failure to deliver a security. A counterparty may fail to deliver a specific security because it misunderstood the terms of the trade, because it is having operational problems, or because it simply does not have the security (having not yet received it from another counterparty, for example, in a "daisy chain" of fails; Fleming and Garbade, 2002). Failing is not viewed as defaulting (Duffie, 1996); in fact, a "fail is understood to be an economic decision by the lender…and carries no particular stigma" (Jordan and Jordan, 1997).

Fails can happen in either the cash or the repo market. If a short seller fails to deliver in the cash market, the delivery is rescheduled for the next day at the same price, and the short loses the time value of the purchase price for a day. In the repo market, if a repo borrower fails to deliver on the first leg of the transaction, the transfer is rescheduled for the next day, but the repo borrower still must pay the agreed-upon interest. Term repos (repos lasting longer than one day) that experience fails will still terminate on the originally scheduled date. Finally, if a reverse lender fails to deliver on the second leg of a transaction, the transfer is rescheduled for the next day; the borrower pays 0% interest for the extra day. (See Fleming and Garbade, 2004, and Fleming and Garbade, 2002.)

After 9/11, a tsunami of fails occurred, going from about $45 B per week before the attacks to $1.4 T for the week ending September 19 (Ip and Zuckerman, 2001). The earliest problems were spurred by the operational problems created by the damage suffered by one of the only two clearing banks, Bank of New York. Then, once the market reopened, many market participants fled to the safety of Treasury securities, and held them as rates fell. Lower rates meant less incentive for bond mutual funds—usually active participants in the repo market—to lend there. Foreign central banks also held their Treasuries, fearing fails. Mortgage-backed securities were repaid early, and their owners reinvested in Treasuries. Thus, as Treasuries were held or absorbed into "off-the-street" portfolios, the supply available for repo transactions dwindled.

Shortages leading to chronic fails can be eased by increasing the lendable supply of a security or increasing the cost of a fail (for example, by instituting a penalty fee; Fleming and Garbade, 2002). The Fed therefore increased supply by increasing the proportion of a specific issue that it would lend from its own portfolio (from 45% to 75%), and almost tripled the dollar amount available to any one dealer. However, the Fed can only lend what it owns, and to meet demand after 9/11, it did not own enough. As the volume of fails

grew and settlement continued to be "stone-age," regulators "worried that it might only be a matter of time before a dysfunctional repo market began to impair the Treasury market itself" (Zuckerman and Ip, 2001).

Thus, on October 4, the Treasury held a "snap" auction and reopened the ten-year note, increasing the size of the issue by 50% with no notice and with no underlying need to borrow. The reopening was simply meant to alleviate the shortage of the note—which it did—leading its specials rate to rise from less than 0.40% to more than 1%. This was the first time that the Treasury had reopened a note in a snap auction, and it "surprised the bond market" (Zuckerman and Ip, 2001).

The move led market participants to expect another reopening (in the five-year note), but this one did not materialize. On October 10th, market strategists had been saying that "At this point, the biggest surprise would be for [the five-year reopening] not to happen," but by the 11th , their line had switched to "We're now skeptical that they're going to do this additional five-year" sale (Downey and Derby, 2001, and Christie, 2001, respectively).

The fact that Treasury did not reopen the five-year underscores how unusual the ten-year move was. As Fleming and Garbade (2002) note, reopening an issue can have significant drawbacks. Some market participants think reopenings reward short-sellers and penalize long-term investors by driving down bond prices (Downey and Derby, 2001). In addition, by disrupting the Treasury's auction patterns—and by borrowing money that is not needed—reopenings introduce market uncertainty, which can increase borrowing costs. Thus, as an analyst commented after the ten-year reopening, "Treasury doesn't want the market to think it's going to respond to every whiff of a squeeze" (Christie, 2001).

These repo market impacts of 9/11 offer students both macro and micro insights into the financial markets. The big picture is that there is a lot of plumbing that keeps financial markets functioning, unhyped by ringing bells and media coverage. The government can influence—not control—this market, but some sorts of interventions are extremely rare. The micro lesson is that the repo market, in particular, has many norms governing the behavior of its participants, including around failing. We will now consider how those norms were severely tested just two years later.

Negative Repo Rates

In 2003, specials rates actually went negative. Fleming and Garbade (2004) provide an excellent analysis of this unusual market period, which forms the basis for this vignette in lesson two. Instructors should assign this short paper as preparatory reading.

At the time of this disruption, short-term rates were at their lowest levels in 45 years. However, as mentioned earlier, intermediate rates rose sharply during the summer, and market participants began short selling the on-the-run ten-year note to hedge further rate increases. As they then tried to obtain the note to cover these shorts, their demand caused the note's specials rate to fall to zero, and shorts began to fail.

With a 0% specials rate, failing to deliver leaves a short-seller in the same position as if she had reversed in the securities to avoid a fail: either way, she delivers the securities to someone tomorrow, with no change in price. If she fails to deliver on her short sale, she has to wait an extra day to receive her cash. If she instead avoids the fail by reversing in the securities, she lends at 0%, waiting a day to receive the same amount of cash. Thus, since she can always choose to fail, a short-seller should not *pay* money—lend at a negative specials rate—to avoid a fail.

Not surprisingly, in 2003, dealers found a way to turn the market's incentive structure into profits: failing on purpose. First, they arranged a term repo, borrowing money at the 0% specials rate. This obliged them to pay interest, even if they failed, but—at a rate of 0%—this stipulation was hardly onerous. Then, they

waited for the specials rate to rise. When it did, they lent at this new, higher rate, borrowing the loan money using the original 0% repo (which had been sitting dormant, waiting to be called upon). Borrowing at 0% while lending at more than 0% equals profit!

Eventually, the epidemic of fails—and the associated strategic games—had to end. Dealers were expending back-office resources to keep track of fails, and customers were getting annoyed that their securities were not being delivered. Dealers also had to hold additional capital against "aged" fails, tying up resources. Finally, dealers began to accept negative specials rates, paying interest to lend money, just to clear up their fails.

Going through this unusual 2003 example demonstrates not only the conventions around fails, but also that collateral can sometimes be so valuable that lenders will charge negative interest rates to get it.

From 2008 to Today

The lessons of 2001 and 2003 should prepare students to examine the repo market during the great recession: flights to quality, decreased supply, fails…it is all there. The novelty of the more recent period lies in the breadth of the Fed's response and the repercussions that linger to this day.

According to Gorton, *et al.* (2017), there is "no consensus on the cause of the crisis"; nonetheless, they conclude that the repo market was at the center of it. In mid-2007, financial market participants, facing volatile asset prices and increasing uncertainty, began to worry about the liquidity of their investments and the stability of their counterparties (Hördahl and King, 2008). In the ensuing flight to quality, lenders became less willing to lend in traditional markets—a "virtual shutdown of the unsecured interbank lending market"—so borrowers moved to the repo markets.

However, there was little comfort there. Margin requirements rose as repo lenders refused all but the shortest and highest quality collateral. Term repos "dried up," and by September, "the entire US GC repo market was trading at rates associated with special collateral" (Hördahl and King, 2008). As lenders demanded Treasuries for collateral, while those with Treasuries refused to lend them, the repo rate for Treasuries fell near zero. As was illustrated in 2003, low repo rates reduce the cost of failing; during the 2007-8 crisis, fails increased almost 30 times, exacerbating the supply disruption.

This disruption was devastating for the investment banks that were accustomed to using the repo market to finance highly levered portfolios of assets like mortgage-backed securities and CDOs. For example, Bear Stearns' treasurer "had never worried about the disappearance of repo lending," but as the market dried up, it only took a few weeks for Bear Stearns to fail (Egan, 2018). Copeland, *et al.* (2014) show that the other marquee name, Lehman Brothers, also experienced severe funding stress immediately before its bankruptcy filing, almost like a bank run. In fact, Gorton, *et al.* (2017) assert that the 2007-8 financial crisis was actually "a repo run in two directions": lenders holding non-Treasury collateral ran to get their money back, while borrowers who had used Treasuries for collateral ran to get those Treasuries back.

The government responded to the market upheaval with significant interventions on multiple fronts. As in 2001, the Treasury reopened issues—four this time—to alleviate collateral shortages. They also instituted a 3% fee on fails (Driessen, 2016). Thus, the government used both of Fleming and Garbade's (2002) tools: increasing supply and increasing the cost of failing.

The government also created several new facilities specifically designed to address the crisis. (See Gorton, *et al.*, 2017, for a clear breakdown of the differences among the various facilities created by the Fed in response to the financial crisis.) The Term Auction Facility (TAF) lent cash to depository institutions, backed by collateral. (See Armakolla, *et al.*, 2017, for a discussion of similar measures undertaken by the

European Central Bank.) From 2008-2010, the Primary Dealer Credit Facility (PDCF) did the same for the Fed's primary dealers. The PDCF was designed as the primary dealers' liquidity backstop, consistent with the Fed's desire to have large institutions reduce their reliance on tri-party repos for funding (Reddy, 2008). The PDCF did, in fact, help stabilize the tri-party market (Copeland, *et al.*, 2014), and was especially in demand after the Lehman bankruptcy.

Of most interest for us is the Term Securities Lending Facility (TSLF), which was an auction facility that permitted primary dealers to exchange tri-party market-acceptable collateral for Treasuries for 28 days. This allowed dealers to upgrade non-Treasury collateral, which had been subject to increasing haircuts from a wary market; it also allowed dealers who needed Treasuries to unwind rehypothecation chains to get them. (In a rehypothecation chain, dealers who had received Treasuries in one transaction later sold them in a second unrelated transaction; the TSLF allowed them to return Treasuries to the first counterparty.)

Thus, the repo market was an important conduit for government intervention during the financial crisis. It has continued to grow in importance, as the Fed's extraordinary involvement throughout the great recession—which almost tripled the size of its balance sheet—has led to a need for "normalization" (Leong, 2013). As noted above, this normalization will be effected through the repo market, using a tool that "has the potential to change the fundamental structure of short-term lending markets; alleviate collateral scarcity; reinforce the push for simpler bank capital regulation; and approximate a Fed backstop for big swathes of US money markets" (Mackenzie, *et al.*, 2013). That tool is the overnight reverse repo facility (O/N RRP).

This facility, started in September of 2013, allows a relatively broad set of money market participants (such a money market funds, banks, primary dealers, and government sponsored enterprises) to lend money to the Fed in exchange for some of the Fed's $2 T in Treasury securities. This activity does not change the size of the Fed's balance sheet, since the Treasuries remain as Fed assets, while repos are substituted for reserves on the liability side. Thus, this facility is not designed to shrink the balance sheet (the Fed eventually will effect that by not rolling over maturing securities), but rather to "sop up" the excess cash generated by quantitative easing (Federal Reserve Bank of New York, 2017).

The overnight RRP facility offers multiple benefits. It provides a relatively elastic source of the highest quality collateral to the broad market, helping alleviate the collateral shortage that attended quantitative easing (Durden, 2013). Even more importantly, it provides the Fed the with an effective tool to establish a floor for the fed funds rate.

The Great Recession accelerated to 2008 the Fed's payment of interest on reserves, an innovation originally scheduled to begin in 2011. Allowing banks to earn interest on excess reserves (IOER) meant that they would be unlikely to lend those reserves in the fed funds market for less than the IOER rate, helping the Fed set a floor for the fed funds rate. However, since market participants like money market mutual funds and government sponsored enterprises are not allowed to earn the IOER, their activity in the fed funds market often forced rates below the Fed's target rate (Ihrig, *et al.*, 2015).

Enter the O/N RRP facility, which may create a new "de facto floor for official borrowing costs," "plugging the gap in the interest on excess reserves facility" and "potentially relegating the benchmark fed funds rate to a purely symbolic role" (Spicer and De Costa, 2013). Since cash lenders can park up to $30 B per day with the Fed at a fixed rate, other potential borrowers are forced to compete with "by far the biggest (and most creditworthy) borrower in the repo market" (Durden, 2013). Those potential cash lenders include money market mutual funds and government sponsored enterprises, so the repo facility has broad influence.

The facility thus has given the Fed more control over money rates. The O/N RRP offering rate has become "an anchor for repo rates quoted at different times during the day, reducing intraday volatility" (Senyuz and Tase, 2017). While the Fed has stated that it will use the current RRP facility "only to the extent necessary

and will phase it out when it is no longer needed to help control the federal funds rate" (Federal Reserve System Board of Governors, 2014), the effectiveness of repo rate targeting suggests that repo interventions will remain an important tool for monetary policy, justifying students' investment in studying them.

Having highlighted several examples of the integral nature of the repo market to the economy, we now turn to the third lesson: a more detailed set of transactions examples.

THIRD LESSON: THE STUDENT IS THE DEALER

The final repo lesson for students involves diagramming several typical sets of repo transactions, taken from Fisher (2002). Going through these helps students understand how repos are often deployed, as well as how the step-by-step details play out. Their responses to these scenarios also provide instructors with a tool for assessing the efficacy of the repo module. (The actual assignment is given in the appendix.)

Qualitative Examples

The three scenarios Fisher (2002) presents are a simple cash market intermediation, a "matched book" transaction, and a complicated multi-period hedged position. In this section, we will consider these qualitatively. In the next section, we will use actual recent market data to reconsider the final scenario quantitatively.

In all cases, we will make a few simplifying assumptions. First, we assume that transactions in both the cash market and the repo market settle on the day of the trade. In fact, however, cash Treasury transactions are settled the next day, while repo trades settle the same day (Jordan and Jordan, 1997; also see Duffie, 1996, for a theoretical model incorporating this timing issue.) Second, in the multi-period example, we show the exchange of cash and securities going back and forth at intermediate periods. However, in actual "open" repos, which are renegotiated daily, these exchanges would only occur when the repo arrangement was terminated (Jordan and Jordan, 1997). Third, we will assume that the on-the-run bonds (labeled "new T-bonds" in the graphic) are on special, as is commonly the case (Jordan and Jordan, 1997). Finally, we assume that we are evaluating the transactions from the position of a dealer, so that a "repo" implies borrowing and a "reverse" implies lending. (Note that these terms are switched when a non-dealer, such as the Fed, is the subject; thus, when the Fed borrows, it is said to be doing a "reverse repo." See Fabozzi, 2000, for a discussion of repo market terminology.)

The market participants with whom we may transact in this lesson are listed in Table 3.

Table 3: Market Participants for Third Lesson

BASKERVILLE	He wants to sell an on-the-run T-bond, but not until day after tomorrow (t=2).
IRENE	She always wants a safe, short-term (overnight) investment. She doesn't care if her collateral is on- or off-the-run. She is in the market every day.
HUDSON	She wants to buy a T-bond today (t=0). She doesn't care if it's on- or off-the-run.
BENEDICT	He needs overnight financing for a leveraged position in on-the-run T-bonds. He is in the market every day.
MYCROFT	He wants to buy a T-bond, but not until day after tomorrow (t=2). He doesn't care if it's on- or off-the-run.
WATSON	He wants to sell an (old) T-bond today (t=0).

This table identifies the cash and repo market participants with whom we may transact in the three scenarios of the third lesson.

In the first scenario, the dealer buys an old T-bond and sells it today. (The convention in the Treasury market is to call an issue "old" as soon as it goes off-the-run; when the next issue come out, this "old" issue becomes "old, old," and so on. We use "old" just to mean "off-the-run.") This scenario helps orient students to the players and their motivations, and illustrates the simplest way that a dealer can make money.

All she needs to do here is buy a bond at her bid from WATSON in the cash market, then sell it at her ask to HUDSON in the cash market, earning the spread. Easy!

The second scenario brings in the repo market. This is a "matched book" transaction (see Jordan and Jordan, 1997, for another example here). Whereas the first example required the dealer to take offsetting positons in the cash market, here she will do so in the repo market. Reviewing the list of market participants, we see that IRENE and BENEDICT are the repo market players: IRENE is an investor (like a money market mutual fund, perhaps), while BENEDICT is a borrower (perhaps a broker or other institution without access to funding sources like customer deposits). The dealer accommodates both.

The dealer enters into a repo transaction with IRENE, borrowing her money against suitable collateral. Where does that collateral come from? From BENEDICT. With BENEDICT, the dealer does a reverse: reversing in his securities (so she can give them to IRENE) and lending him IRENE's money.

The next day, both repo market transactions unwind. BENEDICT repays his loan to the dealer, plus interest; the dealer takes that money, repays her own loan to IRENE, retrieving the collateral which she then returns to BENEDICT. The dealer profits on the difference between the money paid to IRENE and the money received from BENEDICT.

Now that students have seen both a cash market and a repo market transaction, they are ready to put them together. The third scenario not only asks them to use both markets, but also requires them to deal with multiple days. In this case, the dealer buys an old T-bond today, but must wait two days before a buyer appears. In the meantime, she will want to hedge her long position in the old bond by selling short an on-the-run bond (recall that hedging is easiest using the most liquid bond).

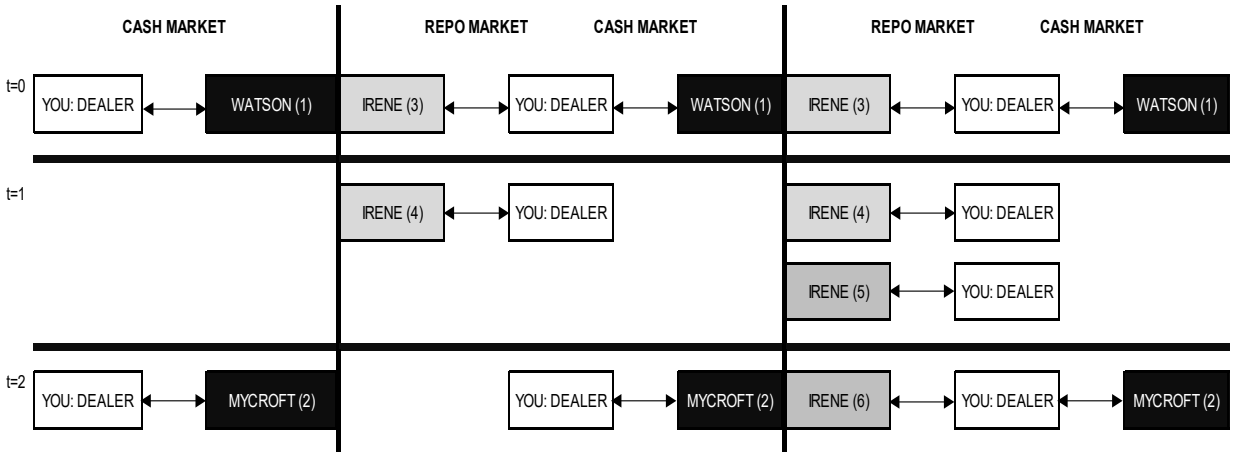
The full three-period scenario is diagrammed in Figure 2, which includes detailed step-by-step notes. However, students should approach this complex sequence in a smaller-picture, systematic way, as we demonstrate in Figure 1. This approach encourages them to focus on the underlying position (here, a long position in the old bond), and to recognize that the repo market transactions are used simply to accommodate that position.

In Figure 1, we work from left to right. The leftmost panel diagrams the underlying position: a long position in an old bond. This position is motivated by the dealer's expectation that prices will rise. She therefore needs to buy low at t=0: this is the cash market transaction shown at the top, in which the dealer buys from the cash-market seller, WATSON. This long position will be unwound at t=2, when the dealer sells this old bond to the cash-market buyer, MYCROFT. (If all goes as the dealer expects, the selling price to MYCROFT at t=2 will exceed the buying price from WATSON at t=0.) Everything that happens in the repo market simply happens to accommodate these two transactions.

To make the t=0 purchase happen, the dealer needs money. She will borrow this in the repo market. She can use the old bond she bought as collateral for a loan from IRENE. We see this in the middle panel of Figure 1: the dealer employs the repo market to get what she needs to effect her fundamental transaction in the cash market.

The problem with borrowing money from IRENE at t=0 is that the dealer needs to repay that loan at t=1. Where will she get the money? From IRENE! At t=1, the dealer and IRENE simply repeat their repo transaction. (Again, most repos are "open" repos, where the cash-for-collateral arrangements are renegotiated daily.) The central panel of Figure 1 shows the t=0 transaction with IRENE unwinding at t=1; the third panel then adds the additional t=1 repo and its t=2 unwind. Now, we've made all the links between t=0 and t=2.

Figure 1: The Step-by-Step Approach to Scenario #3 (without Hedge)



In this figure, we diagram the essentials of the long position for the third scenario. The left-hand panel isolates the underlying long transaction: we buy low at t=0, and sell high at t=2. The middle panel adds the repo transaction that allows the dealer to buy a bond at t=0. The right-hand panel completes the picture by adding the second repo that allows the dealer to keep the position open from t=1 to t=2.

Figure 1 describes the long position, but we also need to consider the hedge. Since the underlying position is long, the hedge must be short. The dealer will therefore take a short position in the hedging instrument, an on-the-run bond. First, at t=0, the dealer sells the new bond in the cash market to HUDSON. She will close this short at t=2 by buying a new bond from BASKERVILLE. To effect these transactions, she must reverse in a bond at t=0, with BENEDICT as counterparty; BENEDICT gets a loan, using the money from the bond sale. This reverse repo then must be unwound and repeated at t=1. All of these transactions are diagrammed and described in Figure 2.

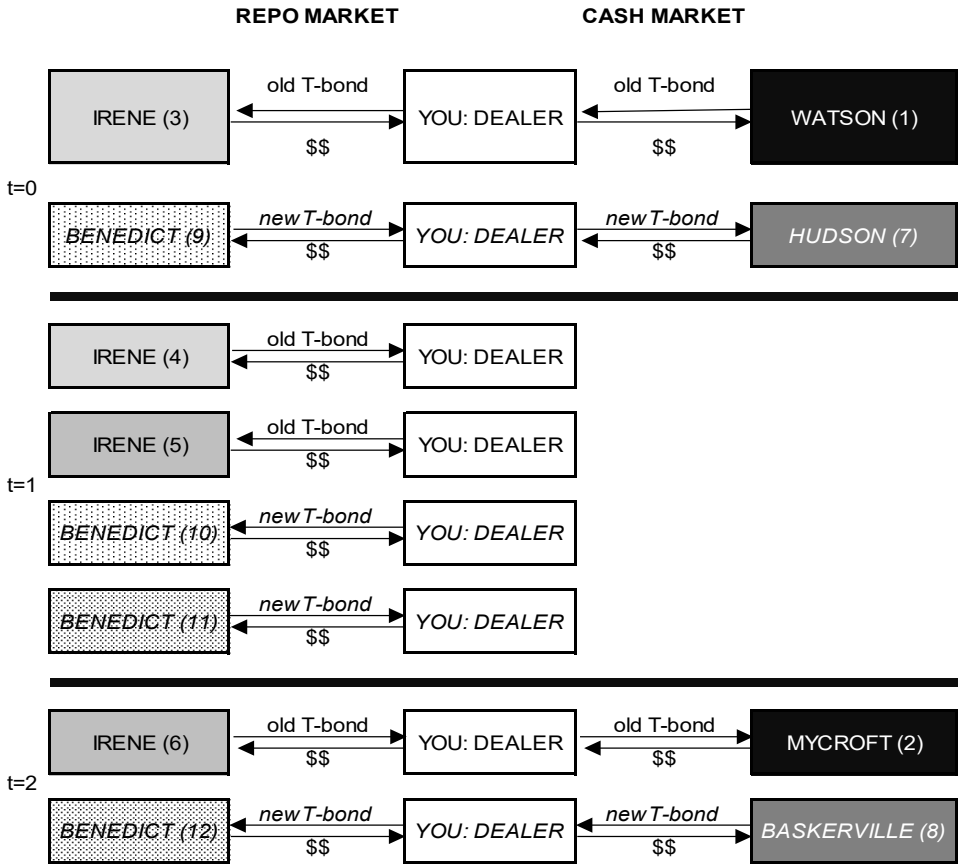
With this qualitative description in hand, we are ready to use actual quotes to see how the dealer makes money from these sorts of transactions.

Numerical Example Using the Two-Period Hedged Transaction

We will assume that the old bond purchased at t=0 is a 5-year T-note with a coupon rate of 2.875% and a YTM of 2.997%. (These are the characteristics for the note issued 10/1/18, with a maturity date of 9/30/23.) The price of this bond at t=0 is therefore $994.3740, assuming 10 periods to maturity. We will ignore accrued interest and any "haircut"—a discount in the amount lent against collateral to account for default risk—throughout this example. (For a numerical demonstration incorporating these issues, see Duffie, 1996. Incorporating accrued interest in the repo price has been standard practice since 1982, when a government securities' dealer's strategy of borrowing securities at prices excluding interest while selling them short at prices that included interest led to the dealer's "spectacular collapse"; see Acharya and Öncü, 2011.)

We use the New York Fed's broad general collateral rate (BGCR) of 10/11/18, 2.14%, for the general collateral repo rate (Federal Reserve Bank of New York, 2018). In Jordan and Jordan's (1997) sample of 50 T-notes that were on special in the early 1990s, the special rates were 10-400 bp below the general collateral rate, with an average discount of 123 bp (32% of the GC rate). Applying this same discount to our GC rate of 2.14% implies a specials rate for our example of 1.46%.

Figure 2: Scenario #3 by Period



STEPS	THE POSITION	
1&2	original long position	You buy an old T-bond at t=0 (step 1). This is a long position. You will profit by selling this old bond for a higher price at t=2 (step 2)
3&4	finance your long position for first period	You need money to buy the old bond at t=0. You get it from IRENE in the repo market: you repo out the bonds and get an overnight loan (step 3). You pay her back at t=1 and get the old bond back (step 4).
5&6	finance your long position for second period	You still need financing at t=1, because you don't yet have a buyer for your old bond. You repeat your repo with IRENE (step 5). At t=2, you repurchase your old T-bond from IRENE (step 6), completing the second repo, then sell the bond to MYCROFT to complete your long trade (step 2).
	THE HEDGE	
7&8	*hedge your long with a short*	*You take a long position in the old T-bond, so you need to hedge with a short. You thus must sell a new T-bond at t=0. You sell to HUDSON. (Step 7 hedges step 1.) You will unwind this short hedge by buying a new T-bond from BASKERVILLE at t=2 (step 8).*
9&10	*accommodate the hedge with a reverse repo*	*You need a new T-bond that you can sell to HUDSON for your hedge. You reverse in this bond from BENEDICT (step 9). You lend to him the money you get from selling the new T-bond to HUDSON (step 7).*
11&12	*repeat the reverse*	*At t=1, you need to return the bond to BENEDICT (step 10). But, as with IRENE, you're not ready to unwind your position yet. You therefore repeat your reverse at t=1 (step 11). At t=2, you will return the bond that you reverse in, using the loan repayment from BENEDICT to pay for the new T-bond from BASKERVILLE (step 8).*

Figure 2 provides the complete long-position-plus-hedge diagram, building on the transactions from Figure 1. The steps are described, and are color-coded to match the relevant parts of the diagram.

To find the implied price of the special 5-year T-note, we will use the no-arbitrage pricing equation from Jordan and Jordan (1997) (based on Duffie, 1996):

$$\text{price of bond on special} = \textit{price of general collateral} * \left[\frac{(1+m*general\ collateral\ rate)}{(1+m*specials\ rate)}\right], \qquad (1)$$

where *m* is the number of days that the bond is expected to trade special, and the daily rates are the relevant quoted rates divided by 360 (the annualizing convention in the money market).

We will assume that our special note has *m*=2, to correspond with the length of our hedge. Our specials price is therefore \$994.3740*{[1 + 2*(.0214/360)]/[1 + 2*(.0146/360)]} = \$994.4115. This is \$0.0375 higher than the GC note, a difference equal to 2*[\$994.370*(.0214/360) - \$994.4115*(.0146/360)] = *m**[GC price*(GC daily rate) – specials price*(specials daily rate)].

Since the special's price falls as the term of its remaining "specialness" falls, we will see the special's price fall at t=1 to \$994.3740*{[1 + 1*(.0214/360)]/[1 + 1*(.0146/360)]} = \$994.3928 (we will assume that the GC note's price stays the same; as Duffie, 1996 notes, this is a common real-world practice when repos are renewed). At t=2, the note goes off special, so its price will converge to the GC price. We will assume that our long position is profitable: yields fall by 24.7 bp to 2.750% at t=2, making the 5-year note price \$1,005.8022.

Now we can quantify the outcome of our two-period hedge. We will consider it both by period and by function. We start with the latter.

The fundamental position is long in the old (GC) T-note. We buy the bond at t=0 for \$994.3740 and sell it at t=2 for \$1,005.8022, making \$11.4282 (steps 1 and 2 in Figure 2). To hedge, we sell short the special T-note at t=0, receiving \$994.4115; we close our short at t=2 by buying the bond for \$1,005.8022, paying \$11.3907 for the hedge (steps 7 and 8). The net for these cash-market transactions is \$0.0375.

We facilitate the cash market trades using two repos with IRENE (borrowing to finance the long position) and two reverses with BENEDICT (lending the proceeds from our short). Since we assume the GC note is priced at \$994.3740 at both t=0 and t=1, the cost of borrowing from IRENE at the GC rate is 2*(\$994.3740)*(.0214/360) = \$0.1182. The interest we earn from BENEDICT equals [\$994.4115*(.0146/360) + \$994.3928*(.0146/360)] = \$0.0807; the net interest cost is therefore \$0.0375. Overall, considering both the cash market and the repo market trades, we end up at \$0. Now we see why Jordan and Jordan (1997) term the specials-pricing relationship as a "no-arbitrage" result, and why Fisher (2002) describes "convergence trades"—trying to profit from the predictable capital loss that occurs when a bond goes off special—as not profitable on average, since "the systematic movement in prices is offset by the relative financing costs."

Looking at this period by period, we start by earning \$0.0375 by selling the special to HUDSON for more than the cost of the old bond we buy from WATSON. At both t=1 and t=2, we lose \$0.0187, because we have to pay IRENE interest at a higher rate on our repo (the GC rate) than we receive from BENEDICT on our reverse. The rest of what we do at t=2—sell our old bond to MYCROFT and buy a new bond from BASKERVILLE—does not change anything, since the GC and specials prices have converged.

If a dealer expects a profit of zero, why is she going to all this trouble? Fisher (2002) answers by noting that "[i]f all goes well, the dealer earns a bid-ask spread that compensates for the cost of holding and hedging the inventory." In our simplified example, we have ignored the frictions that form the very basis for the dealer's business model. Of course, the dealer must also hope that the expected repo spread (the general

collateral rate less the specials rate) does not fall, forcing her to repurchase the special at a higher price than she expected.

To round out this example, let us consider how this baseline, no-profit situation changes as we change the most novel input *m*, the number of days that the new bond will stay on special.

The *m* term affects the price of the special bond, which in turn affects the interest received on the short hedge. (The GC price is not a function of *m*: thus, the long profit and long interest paid remain constant as *m* rises.) Since *m* falls every day, so does the special's price; when *m* falls to zero, the special's price converges to the GC price. Because the pricing of the special capitalizes the "repo discount," buying the special so that you can borrow cheaply against it is a zero-sum game: any benefit you get from the lower specials rate is taken away by the higher specials price. As we noted above, as long as rates do not change, our twelve-step plan will result in zero profit.

However, our twelve-step plan was initiated by our belief that rates would fall and bond prices would rise—that is why we start everything by buying a bond. In this case, *m* can matter, but it depends on its relationship to our holding period (which we will call *n*). As we have seen, if $m = n$, then the special's price at t=*n* equals the GC price at t=*n*, so *m* only affects the initial specials price and the interest we earn as we lend out the special for *n* days, and the arbitrage-pricing relationship ensures we end up at zero profit. This will also occur if $m < n$, since once the prices converge at t=*n*, there is no further price or rate difference between the long and short legs of our hedged position, so there is no room for profit or loss.

If, on the other hand, the bond will remain on special beyond our holding period ($m > n$), then we will not realize zero profit if rates change. We see this by considering *m* values through 91, restricting our analysis to a reasonable quarter-long period. Also, we still assume that the short price at t=*m* is found using the Jordan and Jordan (1997) equation, so that the specials price at t=*m* is a function of the GC price at t=*m*. (This is consistent with Fisher's, 2002, assertion that on-the-run bonds' prices "tend to move up and down" with off-the-run prices.) At a given value of *m*, the long interest paid exceeds the short interest received; this net interest loss outweighs the gain on the long and short positions. As *m* rises, this gets worse: even though the short interest received rises, more money is lost on the short sale. Thus, the dealer's livelihood is clearly contingent on her ability to earn a bid-ask spread.

CONCLUSIONS

Characterizations of the repo market are consistent: "obscure but massive" (Hilsenrath and Rappaport, 2012); "little known but critical" (Ip and Zuckerman, 2001); "large but relatively opaque" (Hördahl and King, 2008). If the market is so important, why do standard undergraduate textbooks skim over repos by simply noting that they are like collateralized loans?

In this paper, we present three lessons that can help instructors give much more depth and context to their classroom discussions of repos. We start by describing a silly interactive play that should introduce the basic market players and their intentions while illustrating the various interactions among them.

We then outline three historical periods in which repos figured prominently. The most important take-away here is that the repo market undergirds much of the more visible market activity with which students are more familiar. This importance will only increase as the Fed begins to work toward "normalization" after the great recession, a process that will involve increased use of repos. Finally, we go through several dealer scenarios, going from the most basic to the fairly involved. Quantifying the most difficult of these scenarios highlights the value of hedging and the dependence of dealer profits on spreads. Instructors also can use students' ability to graph and explain the qualitative aspects of these scenarios as a way to assess the effectiveness of the repo module.

The lessons in this paper provide a broad overview of the repo market, but they form only a two-day sequence meant to be embedded in a financial markets survey course. More specialized finance courses, and macroeconomics courses focused on monetary policy, could incorporate many more aspects of this complicated market. For example, our third lesson contains two very basic and one very hard example; there is a lot of room for instructors to create scenarios of intermediate difficulty. These could be couched in terms of an examination of the various types of organizations that usually find themselves on either side of a repo transaction (e.g., money market mutual funds and hedge funds: how might they interact in a repo transaction?), a context only tangentially addressed here. Students could even be encouraged to create their own "plays" to describe these interactions. More advanced courses also could extend the numerical example by addressing the transaction timing differences in the repo and cash markets, and incorporating the haircuts applied to various sorts of repo collateral. Finally, there is much room to expand the consideration of international issues, such as the differences between CCP trades and tri-party repos, which our lessons do not address.

While lesson three serves as a type of assessment of the module's efficacy, a more careful examination is warranted. As repos become a much more important and visible part of monetary policy, and thus a more integral part of markets courses, instructors will want evidence identifying the types of exercises that provide students with lasting insight. Thus, assessment is clearly a fruitful avenue for future research. Another is—as just noted—the expanding ways in which the Fed and other central banks use reps to effect monetary policy. The 2007-8 financial crisis demanded new tools, and repos have answered the call. Now, pedagogy just needs to catch up.

APPENDIX: ASSIGNMENT BASED ON FISHER (2002)

(This assignment is assigned as homework, with students encouraged to work in pairs to develop their answers.)

You are a dealer. You start with nothing. You goal in this problem is to figure out how you can take/finance/accommodate various positions that you'd like to take, based on your expectations for Treasury bond prices. You can transact in both the spot/cash (regular) market, and in the repo/reverse market. (We'll just call the latter the "repo" market from now on.)

Remember:

> We can clarify how repos work by considering what happens to the collateral (T-bonds in our example):
>
> **REPO OUT, REVERSE IN**.
>
> You can obtain financing in the repo market, and can also find investment opportunities there (it all depends on which side you're on). When we refer to the "repo" market, we really mean the "repo and reverse" market—both sides are possible. All repo market transactions have two parts: today's and tomorrow's. Don't forget to unwind your transactions!

Here is some background on *you*:

> When dealing with investors in the spot market, you buy at a bid (lower) price and sell at an ask (higher) price. Thus, you earn a spread.
>
> You are able to set different interest rates for your repo and reverse repo transactions. Thus, you have the potential for another spread.

All of the repo market transactions in your world are overnight.
You must finance (fund/accommodate) every position you take, since you start with nothing.

To repeat: you can't buy anything without money, and you can't sell something you don't have!

You may choose to hedge your positions. You use *shorts* to hedge *longs*, and vice versa.

When you hedge, you use the most liquid securities (the on-the-run securities). Thus, the assets you use to hedge may not perfectly match the assets you're hedging. (This is called "basis risk.")

We only care about *your* positions—if your counterparties have positions other than those they have with you, we don't care about how they finance them.

Your potential counterparties are described in Table 3 in the text. Note that some of these potential counterparties sometimes may be unavailable to you, depending on the details of the scenario.

For each of the three scenarios below, explain carefully how you can accomplish your goals (i.e., do what the scenario wants done, and make money). Identify the counterparties you will use (**who**), **how** you will work with them, and **when** your trades will happen. You may need several days to accomplish your objectives, or you may just need today. Be sure to note how you make money in a given scenario. Since we haven't specified any rates or prices, you can just say "higher" or "lower" for "price" and/or "rate." Again, some counterparties may not make sense in a given scenario. Others may be used multiple times in a given scenario. You must be part of every trade: you cannot simply match two counterparties together without your intervention (why would you do that?).

Note that diagrams help enormously with repo problems.

Scenario #1:

You buy an old T-bond today and sell it today.

Scenario #2:

A "matched book" transaction. Here, you just want to be an intermediary. You aren't trading T-bonds for your own portfolio. You take two offsetting positions in the repo market, a long and a short.

Scenario #3:

You buy an old T-bond today, but can't find a buyer today. You will have to wait a few days before a buyer appears. You will hedge the risk of your position using an on-the-run T-bond.

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