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Dealer behavior in the specials market for US Treasury securities ☆

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Abstract

We assess dealer behavior in the specials market for US Treasury securities by comparing dealer participation in the Federal Reserve's securities loan auctions with prices in the private market. Dealer behavior is generally consistent with the law of one price and apparent violations can largely be explained by institutional differences between the private market and the Fed's program. However, for auctions that are effectively noncompetitive, dealers regularly pass up true arbitrage opportunities and frequently overpay to borrow securities. Dealers apparently do not realize that certain auctions are noncompetitive, even though the information needed to discern this fact is publicly available in advance.

JEL classification: G12; E58; H63

Keywords: Securities lending; Repurchase agreements; Federal Reserve; Treasury securities

1. Introduction

One of the basic tenets of financial economics is the law of one price; identical goods have identical prices. Investors acting in their own self interest should generally enforce the law, with arbitrageurs stepping in to correct any mispricings. While violations of the law have been de-

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tected (see Lamont and Thaler, 2003b, for a review), they should presumably be particularly rare in markets where all participants are relatively sophisticated. Despite this, we identify situations in the market for borrowing and lending US Treasury securities where dealers regularly pass up true arbitrage opportunities and frequently overpay to borrow securities.

Markets for borrowing and lending securities have been the focus of increased attention over the past decade. In a path-breaking article, Duffie (1996) describes how fee income from lending a Treasury security supplements the security's principal and interest payments. He hypothesizes that expectations of high loan fees increase the equilibrium price of a security above that which would prevail in the absence of such expectations. Jordan and Jordan (1997) confirm the hypothesis for Treasury notes and Krishnamurthy (2002) provides corroborating evidence for bonds. Keane (1996) observes that loan fees for recently auctioned notes follow a predictable pattern over the course of an auction cycle and Cherian et al. (2004) analyze the implications of this pattern for cash market prices.[1]

Market participants borrow Treasury securities to deliver against short sales and to cure settlement fails. A short sale is a sale of securities that the seller does not own and has to borrow to make delivery. The short seller returns the borrowed securities when it closes out its short position with an offsetting purchase. A settlement fail occurs when a seller does not deliver securities on the date agreed upon with the buyer.[2] Fails occur most commonly when a dealer cannot deliver securities because it failed to receive the same securities in settlement of an unrelated purchase. Such "daisy chain" fails can be cured by borrowing the securities that failed to arrive and then delivering the borrowed securities. The dealer returns the borrowed securities when it receives the securities that it purchased.

Concern over settlement fails led the Federal Reserve to initiate a program to lend Treasury securities from its System Open Market Account in 1969. The Fed revised the program in 1999 by, among other things, introducing daily auctions to make the pricing of its loans a market-driven process. It auctions securities at noon, after the period of greatest liquidity in the over-the-counter securities lending market, to give dealers access to a supplementary source of securities relatively late in the day. It also imposes a minimum fee to deter borrowing of securities that are readily available in the private market.

The Fed is an important lender of Treasury securities. As of December 31, 2005, the Fed owned \$744 billion in Treasury securities, representing 18% of all marketable Treasury securities. It makes up to 65% of its holdings of any given issue available for lending, subject to per-issue and overall dealer borrowing limits. Over our sample period of April 1999 to November 2002, total securities lending by the Fed averaged \$1.5 billion per day. Lending is highly concentrated in securities that are expensive to borrow in the private market, so that over half of the Fed's lending was accounted for by the on-the-run 2-, 5-, and 10-year notes.[3]

We assess dealer behavior in the market for borrowing and lending Treasury securities by comparing dealer participation in the Federal Reserve's securities loan auctions with prices in the private market. We test whether, and the extent to which, dealers borrow securities from the Fed when prices in the private market suggest they should, and whether they do not borrow

[1] Related analyses of the market for borrowing and lending common stock include Apfel et al. (2001), D'Avolio (2002), Duffie et al. (2002), Geczy et al. (2002), Jones and Lamont (2002), and Lamont and Thaler (2003a).

[2] Fleming and Garbade (2002) describe how transactions in Treasury securities settle and why fails occur. DeGennaro and Moser (1990) show how the possibility of fails affects securities prices.

[3] On-the-run securities are the most recently issued securities of a given maturity. First off-the-run securities are the second most recently issued securities of a given maturity.

securities from the Fed when private sector prices suggest they should not. We also test whether the fees paid by dealers in the Fed's auctions are consistent with prices observed in the private market.

We find that dealer behavior is generally consistent with the law of one price and that apparent violations can largely be explained by institutional differences between the private market and the Fed's program. Late-appearing borrowing demands and certainty of delivery can explain why dealers sometimes borrow securities from the Fed at prices higher than those in the private market. Conversely, transaction costs and the relatively late hour of the Fed's securities loan auctions limit the feasibility and attractiveness of borrowing from the Fed for re-lending in the private market and can thus explain why dealers sometimes abstain from borrowing securities from the Fed at prices lower than those in the private market.

However, we also find evidence of suboptimal dealer behavior. Programmatic restrictions on dealer borrowing mean that certain auctions are effectively noncompetitive, so that dealers can borrow securities from the Fed at its minimum fee with certainty. In such cases, dealers regularly pass up riskless opportunities to borrow securities from the Fed for re-lending in the private market at a higher fee. Moreover, while dealers appear to shade their bids in noncompetitive auctions, they frequently pay more than the minimum fee necessary to borrow securities in such auctions. We consider various explanations and conclude that some dealers must not realize that certain auctions are noncompetitive, even though the information needed to discern this fact is publicly available in advance.

The paper proceeds as follows. Section 2 reviews the mechanisms for borrowing and lending Treasury securities. Section 3 describes the history and current structure of the Fed's securities lending program. Section 4 explains our data. Section 5 presents our basic hypotheses, models, and results regarding dealer behavior in the Fed's securities loan auctions. Section 6 explores the consequences of the Fed's programmatic restrictions on dealer borrowing for auction competitiveness and dealer behavior. Section 7 concludes.

2. Borrowing and lending Treasury securities

Most market participants lend and borrow Treasury securities through repurchase agreements ("repos" or "RPs") and reverse repurchase agreements. A participant executing an RP sells securities (typically for same-day settlement) and simultaneously agrees to repurchase the same securities from the buyer at a higher price on a future date. The transaction is tantamount to borrowing money using securities as collateral, where the proceeds of the sale is the principal amount of the borrowing and the excess of the repurchase price over the sale price is the interest paid on the borrowing. The counterparty to the transaction executes a reverse RP, borrowing (or "reversing in") securities against lending money.

There are two types of RPs. A *general collateral RP* is an RP in which the lender of funds is willing to accept any of a variety of Treasury securities as collateral. The lender is concerned primarily with earning interest on its money and having possession of securities that can be sold quickly in the event of a default by the borrower. Interest rates on overnight general collateral RPs are usually quite close to contemporaneous rates on overnight loans in the federal (fed) funds market. This reflects the essential character of a general collateral RP as a device for borrowing and lending money.

A *special collateral RP* is an RP in which the lender of funds wants to borrow a particular security. It is, consequently, a device for borrowing and lending securities rather than borrowing and lending money. The rate on a special collateral RP is commonly called a "specials" rate. The owner of a security may be induced to lend the security if a dealer offers the owner an opportunity to borrow money at a specials rate below where it can re-lend the same funds on a general collateral reverse RP.[4]

The difference between the general collateral rate and the specials rate for a security is a measure of the "specialness" of the security. If the demand to borrow a security is modest relative to the supply available for lending, a borrower of the security will usually be able to lend its money at a rate no lower than about 1/8 to 1/4% below the general collateral rate. If the demand to borrow is strong, or if the supply of the security available for lending is limited, the specials rate for the security may be materially below the general collateral rate and the specialness spread correspondingly large; the security is then said to be "on special." Cornell and Shapiro (1989) and others document instances of large specialness spreads.

Market participants also borrow Treasury securities by pledging collateral and paying the lender a fee. This arrangement accommodates investors who cannot borrow money (as is the case with some institutional investors) and thus cannot lend their securities on RPs. Pledging collateral and paying a fee to a securities lender is economically equivalent to reversing in the securities on a special collateral reverse RP and funding the money lent by borrowing money on a general collateral RP. Consequently, the fee paid to borrow a security is typically about the same as the contemporaneous specialness spread for the security.

General collateral RPs and securities lending transactions are arranged in over-the-counter markets. As in the market for outright purchases and sales of Treasury securities, brokers arrange transactions between dealers on a blind, or undisclosed, basis. Trading begins at about 7:00 a.m. New York time and the markets remain quite active until about 10:30 a.m. Liquidity declines thereafter as participants begin to settle the day's commitments by delivering and receiving securities.

3. The Federal Reserve's securities lending program

The idea of a Federal Reserve securities lending program can be traced back to the 1950s. Ownership of intermediate- and long-term Treasury securities was migrating from banks to pension funds and other emerging classes of institutional investors and some of the new money managers were slow to obtain authorization to lend the investments that they managed. The shrinking stock of securities available for lending led to a rising incidence of settlement fails. The fails led in turn to a decline in market liquidity as dealers became reluctant to accommodate customer purchase interests if they did not already have possession of the securities that customers wanted to buy.[5] Some market participants advanced proposals to allow dealers to borrow securities from the largest owner of Treasury securities, the Federal Reserve's System Open Market Account (SOMA),[6] but none of the proposals came to fruition until 1969.

[4] For a more extensive discussion of the specials market, see Duffie (1996), Keane (1996), Jordan and Jordan (1997), Buraschi and Menini (2002), and Fisher (2002).

[5] US Treasury and Federal Reserve System (1959, pp. 23–24), Meltzer and von der Linde (1960, pp. 94–95), and Federal Reserve Bank of New York (1962).

[6] US Treasury and Federal Reserve System (1959, pp. 23–24), Federal Reserve Bank of New York (1962, 1967), Federal Open Market Committee (1968a, pp. 95–99 and 1968b, pp. 70–81), and US Treasury and Federal Reserve System (1969, p. 18).

3.1. The 1969 program

The spring of 1969 witnessed a sharp increase in fails. To deal with the problem, dealers began to stretch out settlement times and declined to enter into transactions for same-day settlement with other than their best customers. The SOMA manager expressed concern that further deterioration in the settlement process might make dealers reluctant to trade with the Fed for same-day settlement and thus might impair the ability of the Fed to achieve its monetary policy objectives. These concerns provided the impetus for the Federal Open Market Committee (FOMC) to approve a modest securities lending program.[7]

The 1969 program provided for lending Treasury securities to dealers with a trading relationship with the Fed—so-called "primary" dealers—at a fixed fee of 75 basis points per annum for up to three business days. The program was not intended to be an instrument of monetary policy and was designed to function without affecting the market for bank reserves. In particular, the Fed did not lend securities against borrowing money (which would have had the effect of draining reserves from the banking system). Instead, dealers had to collateralize their borrowings with other Treasury securities of comparable value.

The 1969 program limited dealer borrowing in several respects. A dealer could not borrow more than $50 million face amount of any single bill or more than $10 million principal amount of any note or bond, and it could not borrow more than $75 million of securities in aggregate.[8] Additionally, a dealer had to certify that it was borrowing to replace securities that a seller had failed to deliver and not to finance a short sale, and that it had not been able to borrow the securities elsewhere. The certifications were intended to limit loans to a purpose—avoiding and curing settlement fails—closely associated with the execution of monetary policy, and to limit the Fed's role to that of a lender of last resort. The loan fee was set 25 basis points higher than the 50 basis point fee usually charged by private lenders to reinforce the Fed's position as a lender of last resort.

3.2. The 1999 revision

As a consequence of the growth of trading in Treasury securities and in the size and complexity of the securities lending market during the 1980s and 1990s, the Federal Reserve revised its lending program in April 1999. Dealer limits were increased substantially and an auction mechanism was introduced to make loan pricing a market-driven process. The certification requirements were eliminated, enabling dealers to borrow securities for any purpose. However, loans were limited to a single business day to make the program less attractive to dealers financing short sales for a purpose other than to accommodate customer purchase interests.[9]

[7] Federal Open Market Committee (1969a, pp. 79–85, 1969b, pp. 94–97, 1970). See also Federal Reserve Bank of New York (1969) for further evidence of Federal Reserve concern with Treasury fails.

[8] The lending limits were suspended briefly when Drysdale Government Securities, Inc. failed (Wall Street Journal, 1982), when Hurricane Gloria disrupted the New York financial markets in 1985 (Federal Open Market Committee, 1985), and following the break in the stock market in 1987 (Federal Open Market Committee, 1987).

[9] Federal Reserve Bank of New York (1999). Short sales to accommodate customer purchase interests are usually covered within a day or two and are commonly financed with overnight borrowings. Short sales executed as a hedge or as part of a spread trade are commonly financed with open or term borrowings.

Table 1
Terms of the Federal Reserve's securities lending program, April 26, 1999–November 6, 2002

Panel A: Minimum Loan Fee	
April 26, 1999	1.50% per annum
September 18, 2001	1.00% per annum
Panel B: Maximum Percent of SOMA Position in a Security that Can be Lent	
April 26, 1999	25%
September 7, 1999	45%
September 27, 2001	75%
October 18, 2001	45%
May 15, 2002	65%
Panel C: Maximum Amount of a Security that a Dealer Can Borrow	
April 26, 1999	$100 million
September 11, 2001	Unlimited
September 18, 2001	$100 million
September 27, 2001	$250 million ($100 million for the 5% note of August 15, 2011 and the 4.25% note of November 15, 2003)
October 3, 2001	$250 million ($100 million for the 5% note of August 15, 2011)
October 18, 2001	$100 million
May 15, 2002	$200 million
Panel D: Maximum Total Amount of Securities that a Dealer Can Borrow	
April 26, 1999	$500 million
September 11, 2001	Unlimited
October 18, 2001	$500 million
May 15, 2002	$1 billion

Note: The table reports the terms of the Federal Reserve's securities lending program from its April 26, 1999 revision through November 6, 2002. Program provisions and changes are posted at the Federal Reserve Bank of New York's website at http://www.newyorkfed.org/markets/securitieslending.html.

Under the revised program, at noon each business day the Federal Reserve Bank of New York offers to lend up to 65% of the amount of each Treasury security with a maturity of two weeks or longer beneficially owned by SOMA, subject to an upper limit of the amount of the issue actually in SOMA's account, i.e., not already out on loan. (As shown in Table 1, the terms of the program have been modified several times since 1999. The text describes program provisions as of the end of our sample period in November 2002.) Primary dealers bid for a loan of a specific security by specifying the quantity desired (in increments of $1 million) and a loan fee. The Fed imposes a minimum fee of 1% to deter dealers from borrowing securities that are not on special and that are readily available from private lenders. Bids are accepted until 12:15 p.m.

After the auction close, loans are awarded to the highest bidders at their bid rates until all of the securities available for lending have been allocated or all of the bidders have been satisfied (so this is a multiple-price, and not a single-price, auction). Awards are subject to the limitations that a dealer cannot borrow more than $200 million of any single issue or more than $1 billion of securities in aggregate. Within minutes of the auction close the Fed informs each participating dealer which of its bids were accepted. It also announces publicly the total amount lent of each security and the weighted average loan fee for each security. Table 2 gives an example of the auction results made public.

Table 2
Securities loan auction results for February 1, 2000

Security description	Total amount lent	Weighted average fee
5–1/2% note of March 31, 2000	$17 million	1.50%
6% note of August 15, 2004	$100 million	1.50%
5–7/8% note of November 15, 2004	$984 million	2.93%
6% note of August 15, 2009	$1540 million	4.17%
6–1/8% bond of August 15, 2029	$483 million	4.37%

Note: The table reports summary results of the Federal Reserve's securities loan auction for February 1, 2000 as posted to the Federal Reserve Bank of New York's website at http://www.newyorkfed.org/markets/seclend/sec_lendop.cfm.

3.3. Why dealers borrow securities from the Federal Reserve

Dealers borrow securities from the Fed to satisfy late-appearing borrowing demands, to reduce their financing costs, and to earn trading profits. As noted above, the over-the-counter securities lending market is less active at midday compared to 8:00 or 9:00 a.m. If a dealer determines late in the morning that it needs to borrow a security, it may not be able to locate an owner willing to lend the needed quantity at a price near the specialness spread prevailing in the private market. The dealer may then choose to submit a bid in the Fed's auction. The Fed purposely set the time of its auctions at noon to give dealers access to a supplementary source of securities late in the day.

Additionally, dealers anticipate auction outcomes when they borrow and lend securities earlier in the day. In particular, they seek to lend securities at specials rates lower than those consistent with expected auction loan fees (thereby attempting to earn trading profits) and they abstain from borrowing needed securities at such rates (thereby attempting to reduce their financing costs). A dealer might, for example, lend a security at a specials rate of 1% when the general collateral rate is 3% (i.e., at a specialness spread of 2%) if it thinks it will be able to borrow the same security from the Fed for a fee of 1–1/4%.

4. Data

Our primary data set consists of the publicly announced results of the Federal Reserve's securities loan auctions from April 26, 1999 to November 6, 2002, including the aggregate amount of, and average loan fee for, each security lent.[10] (Fee and quantity data on loans to individual dealers are not publicly available, nor are data on individual or aggregate dealer bids.) The sample interval begins with the first auction under the revised lending program and ends the day the FOMC lowered the target fed funds rate to 1–1/4%. The latter action left only a 1/4% gap between the general collateral rate—the maximum fee that market participants are generally willing to pay to borrow a security—and the Fed's minimum loan fee of 1%.

On average, the Fed lent $1.5 billion principal amount of securities, and 4.6 different issues, per day over the sample period. There was no lending on 38 (4.3%) of the 892 days on which auctions were conducted. Lending peaked in terms of number of issues (69) and amount lent

[10] This information is posted after each auction to the New York Fed's website at http://www.newyorkfed.org/markets/seclend/sec_lendop.cfm. Historical data are available at http://www.newyorkfed.org/markets/seclend/historical/search.cfm.

($13.4 billion) on September 11 and September 27, 2001, respectively.[11] The average loan fee equaled the minimum loan fee on 2354 (57.3%) of the 4105 security-days over the sample period and exceeded the minimum loan fee on 1751 (42.7%) of the security-days.

Securities lending activity is highly concentrated in on-the-run and first off-the-run notes, reflecting the frequency with which these securities trade on special compared to other securities. The on-the-run 2-, 5-, and 10-year notes account for 56.1% of the quantity of securities lent over the sample period, even though these three issues represent only a small fraction of the approximately 200 issues outstanding on any given day.[12] First off-the-run notes account for an additional 16.4% of lending and other notes for 14.0%. Bonds account for only 2.4% of lending, reflecting the fact that bonds rarely traded on special over the sample period. Bills account for the remaining 11.1% of lending.[13]

Our second data set contains the general collateral repo rate and the specials rates for the on-the-run and first off-the-run 2-, 5-, and 10-year notes as of 10:00 a.m. each day. (Rates as of the time of the Fed's auctions at noon—when the over-the-counter securities lending market is less liquid—are not available.) The repo rates are bid rates based on surveys of randomly selected dealers and are reported by GovPX through online information vendors. This data is available for 799 days from July 15, 1999 to November 6, 2002, excluding the interval from September 11 to October 9, 2001.

5. Three tests of the law of one price

We test three hypotheses derived from the law of one price regarding dealer behavior in the Federal Reserve's securities loan auctions. First, we test whether the *incidence* of borrowing from the Fed is consistent with dealers participating in an auction when, and only when, participation gives them an opportunity to lower their financing costs or earn trading profits. Second, we test whether the *quantity* of borrowing from the Fed is consistent with dealers fully exploiting opportunities for cost savings and trading profits. Third, we test whether the fees paid by dealers in the Fed's auctions are close to the costs of borrowing the same securities in the private market.

5.1. Borrowing incidence

We conjecture that the proximate determinant of whether a dealer borrows a security from the Fed is the cost of borrowing the security in the private market, i.e., the specialness spread between the general collateral repo rate and the security's specials rate. In particular, we hypothesize that, in the absence of transaction costs and other market frictions, at least one dealer will borrow a security from the Fed if the specialness spread exceeds the Fed's minimum loan fee. Conversely, we hypothesize that no dealer will borrow a security from the Fed if the specialness spread is less than the minimum loan fee.

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[11] Fleming and Garbade (2002) explore the settlement problems and related surge in securities lending that followed the September 11 attacks.

[12] Excluding inflation-indexed securities, there were 229 Treasury bills, notes, and bonds outstanding on April 26, 1999 and 167 issues outstanding on November 6, 2002.

[13] Bills do not typically trade on special (Fleming, 2002, p. 711). The bill maturing March 1, 2001 accounts for 35.1% of all bill lending over the sample period. This bill was the last 52-week bill issued on a 4-week cycle before the Treasury reduced the issuance frequency to every 13 weeks. The bill became quite expensive in the specials market (Fleming, 2000).

To express our hypothesis in an analytical form, let Φ be an indicator variable such that $\Phi = 1$ if at least one dealer borrows a particular security from the Fed on a given day and $\Phi = 0$ if no dealer borrows the security. Let $\tilde{S}$ denote the specialness spread for the security at the time of the Fed's securities loan auction and let $F_{\min}$ denote the Fed's minimum loan fee. Ignoring transaction costs and other market frictions, Φ should depend on $\tilde{S}$ and $F_{\min}$ as:

$$\Phi = \begin{cases} 0 & \text{if } \tilde{S} < F_{\min}, \\ 1 & \text{if } \tilde{S} > F_{\min}. \end{cases} \tag{1}$$

If $\tilde{S} < F_{\min}$, $\Phi = 0$ because no dealer should be willing to pay more to borrow the security from the Fed than the contemporaneous cost of borrowing the security in the private market. Conversely, if $\tilde{S} > F_{\min}$, $\Phi = 1$ because if $\Phi = 0$ a dealer who would otherwise pay $\tilde{S}$ to borrow the security in the private market could bid $F_{\min}$ for the security, have its bid accepted, and thereby reduce its financing costs. Additionally, if $\tilde{S} > F_{\min}$, $\Phi = 1$ because if $\Phi = 0$ a dealer with no a priori reason to borrow or lend the security could profit by bidding $F_{\min}$ for the security, having its bid accepted, and then re-lending the issue in the private market at $\tilde{S}$.

We cannot test the model in Eq. (1) directly because we observe specialness spreads at 10:00 a.m. rather than the time of the Fed's auctions at noon. However, let S denote the specialness spread at 10:00 a.m. and suppose, for simplicity, that $\tilde{S} = S + \xi$, where ξ is a normally distributed random variable with mean zero and variance ω^2.[14] We can then write Eq. (1) as:

$$\Phi = \begin{cases} 0 & \text{if } S + \xi < F_{\min}, \\ 1 & \text{if } S + \xi > F_{\min}. \end{cases} \tag{2}$$

It follows that, conditional on the difference between S and $F_{\min}$, the probability that $\Phi = 1$ is:

$$\Pr[\Phi = 1 \mid S - F_{\min}] = \int_{-\infty}^{(S-F_{\min})/\omega} n(z) \cdot \mathrm{d}z \tag{3}$$

where $n(z)$ is a standard normal probability density function.

Eq. (3) is a special case of a probit model (Greene, 1997, Chapter 19):

$$\Pr[\Phi = 1 \mid S - F_{\min}] = \int_{-\infty}^{\beta_0+\beta_1\cdot(S-F_{\min})} n(z) \cdot \mathrm{d}z. \tag{4}$$

Comparing Eqs. (3) and (4) shows that we expect $\beta_1 > 0$, so that a wider specialness spread is associated with an increased probability of borrowing from the Fed, and $\beta_0 = 0$, so that the probability of borrowing from the Fed equals 50% when the 10:00 a.m. specialness spread equals the minimum loan fee. The specialness spread at which the probability of borrowing equals 50% is the value of S that satisfies the equation $\beta_0 + \beta_1 \cdot (S - F_{\min}) = 0$, or $S_{50\%} = F_{\min} - \beta_0/\beta_1$.

[14] Our assumption that ξ is normally distributed is convenient but cannot be literally true. A specialness spread cannot go below zero because a security's specials rate cannot exceed the general collateral rate. Moreover, a specialness spread will hardly ever exceed the general collateral rate because—outside of highly unusual circumstances—specials rates do not go below zero. (See Fleming and Garbade, 2004, for a discussion of negative specials rates.) It follows that ξ cannot be less than $-S$ (if $\xi < -S$ then $\tilde{S} < 0$) and will hardly ever exceed the security's specials rate (if $\xi > Rs$, then $\tilde{S} > Rg$, where Rg is the general collateral rate and Rs is the specials rate).

Table 3
Probit model estimates of the incidence of borrowing

β_0	β_1	$S_{50\%} - F_{\min}$	N
0.501	2.025	−0.248	4791
(0.044)	(0.055)		
[<0.001]	[<0.001]		

Note: The table reports probit model estimates of the incidence of at least one dealer borrowing a security in a Federal Reserve securities loan auction. The probability that at least one dealer borrows a security ($\Phi = 1$) when the security's 10:00 a.m. specialness spread (in percent) is S and the Fed's minimum loan fee (in percent) is $F_{\min}$ is:

$$\Pr[\Phi = 1 \mid S - F_{\min}] = \int_{-\infty}^{\beta_0+\beta_1\cdot(S-F_{\min})} n(z)\cdot \mathrm{d}z.$$

Standard errors of estimates are in parentheses and p-values on the null hypothesis that a coefficient is zero are in brackets. The specialness spread at which the probability of borrowing equals 50% is the value of S that satisfies the equation $\beta_0 + \beta_1 \cdot (S - F_{\min}) = 0$, or $S_{50\%} = F_{\min} - \beta_0/\beta_1$, so that $S_{50\%} - F_{\min} = -\beta_0/\beta_1$.

Table 3 presents estimates of β_0 and β_1 for our pooled sample of on-the-run and first off-the-run notes.[15] As expected, $\hat{\beta}_1$ is positive and highly significant, showing that the incidence of dealer borrowing from the Fed increases with a security's specialness spread. This relationship is also evident from Fig. 1, which plots the fitted probability and actual frequency of borrowing against the difference between the specialness spread and the minimum loan fee. Figure 1 also shows that the actual borrowing frequencies track the fitted probabilities fairly well. The incidence of dealer participation in the Fed's securities loan auctions thus appears reasonably consistent with the law of one price.

Contrary to expectations, however, $\hat{\beta}_0$ is significantly greater than zero. The transition point at which the probability of borrowing from the Fed equals 50% occurs when the 10:00 a.m. specialness spread is about 25 basis points below the minimum loan fee ($S_{50\%} = F_{\min} - 0.25$ when $\beta_0 = 0.501$ and $\beta_1 = 2.025$). The unexpectedly high dealer propensity to borrow securities from the Fed when the 10:00 a.m. specialness spread is less than the minimum loan fee may reflect late-appearing borrowing demands, as discussed earlier. It may also reflect a willingness of dealers to pay a premium for certainty of delivery. Unlike private market lenders, the Fed never fails to deliver collateral.[16]

5.2. *Quantity borrowed*

We conjecture that a security's specialness spread in the private market is also the proximate determinant of the quantity of the security borrowed from the Fed. In particular, we hypothesize that, in the absence of transaction costs and other market frictions, dealers will borrow as much as they can from the Fed if the specialness spread at the time of a securities loan auction exceeds the Fed's minimum loan fee. However, we also recognize that transaction costs and other market

[15] All reported results are based on the pooled sample of notes. The results in this section are the same qualitatively for the 2-, 5-, and 10-year notes individually. The next section considers auction competitiveness, which differs across notes because of the manner in which the Fed's portfolio is managed. Nonetheless, the results there do not suggest any systematic differences in dealer behavior across securities.

[16] Fleming and Garbade (2004) show that dealers were willing to pay the Fed a premium for certainty of delivery of a particular 10-year note in 2003.

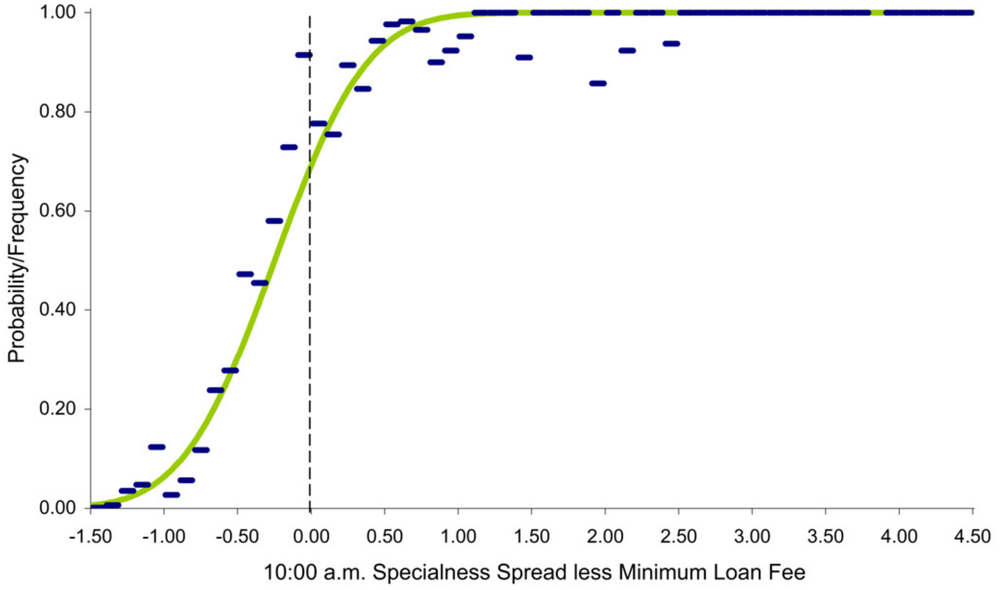

Fig. 1. Fitted probability and actual frequency of borrowing. The figure plots the fitted probability and actual frequency of at least one dealer borrowing a security in a Federal Reserve securities loan auction against the difference between the specialness spread for the security at 10:00 a.m. (measured in percent) and the Fed's minimum loan fee (also measured in percent). The actual frequency of borrowing is estimated for each 10 basis point interval, inclusive of observations at the lower boundary of the interval.

frictions may limit the ability of a dealer to profit from differences between specialness spreads and the minimum loan fee and hence limit demand for borrowing.

To express our hypothesis in an analytical form, let Q denote the total amount of a security borrowed from the Fed on a given day and let $Q_{\max}$ denote the maximum amount of the security that could have been borrowed. $Q_{\max}$ is the lesser of

(a) the maximum amount of the security that the Fed can lend (the product of the maximum fraction of a SOMA position that can be lent and the size of the SOMA position), and
(b) the maximum amount of the security that dealers in aggregate can borrow (the product of the maximum amount of the security that a single dealer can borrow and the number of primary dealers).[17]

Ignoring transaction costs and other market frictions, Q should depend on $\tilde{S}$ and $F_{\min}$ as:

$$Q = \begin{cases} 0 & \text{if } \tilde{S} < F_{\min}, \\ Q_{\max} & \text{if } \tilde{S} > F_{\min}. \end{cases} \tag{5}$$

If $\tilde{S} < F_{\min}$, $Q = 0$ because no dealer should be willing to borrow the security from the Fed if it is cheaper to borrow in the private market. Conversely, if $\tilde{S} > F_{\min}$, $Q = Q_{\max}$ because if

[17] As mentioned, dealers are also limited in the quantity of securities they can borrow in aggregate, but we do not have data on the bidding or borrowings of individual dealers and thus cannot model this constraint.

$Q < Q_{\max}$ a dealer bidding $F_{\min}$ for the security would have its bid accepted and be able to re-lend the security in the private market at a profit.

Defining the borrowing ratio κ as $\kappa = Q/Q_{\max}$, we can write Eq. (5) as:

$$\kappa = \begin{cases} 0 & \text{if } \tilde{S} < F_{\min}, \\ 1 & \text{if } \tilde{S} > F_{\min}. \end{cases} \tag{6}$$

Comparing this model to the model for Φ in Eq. (1) shows that the borrowing ratio should be perfectly correlated with whether any borrowing occurs, i.e., $\kappa = 1$ if and only if $\Phi = 1$. Dealers should borrow as much as they can from the Fed if they borrow at all.

5.3. The effect of transaction costs and other market frictions

Transaction costs and other market frictions can distort the borrowing function in Eq. (6) by increasing κ above zero for some values of $\tilde{S}$ less than $F_{\min}$ and by depressing κ below one for some values of $\tilde{S}$ greater than $F_{\min}$. As noted earlier, a dealer may be willing to pay $F_{\min}$ to borrow a security from the Fed even when $\tilde{S}$ is less than $F_{\min}$ because of late-appearing borrowing demands or because it values certainty of delivery. This implies that κ may be positive even when $\tilde{S}$ is less than $F_{\min}$.

Conversely, when $\tilde{S}$ is greater than $F_{\min}$, transaction costs and market illiquidity may limit auction bids motivated by the prospect of securing securities for re-lending in the private market at a higher fee, thereby depressing κ below one. For example, if $\tilde{S}$ is only 10 basis points greater than $F_{\min}$, the gross gain on \$10 million of securities borrowed at $F_{\min}$ and lent at $\tilde{S}$ for one day is only \$27.78 (\$27.78 = 0.10% ∗ \$10 million ∗ 1 day/360 days per year). To secure this gain, a dealer must borrow securities from the Fed, re-lend the securities on a special collateral RP, and then re-lend the funds borrowed on the special collateral RP on a general collateral reverse RP. In addition to transaction costs, market illiquidity increases the risk that the securities cannot be relent at the prevailing specialness spread (due to limited market depth or changes in the spread after the auction close).

If different dealers incur different transaction costs and have different risk tolerances, then some but not all dealers may borrow securities from the Fed at values of $\tilde{S}$ greater than $F_{\min}$. Since borrowing by any single dealer is limited, each participating dealer may borrow its maximum amount without pushing aggregate borrowing to $Q_{\max}$. Such occasions might be particularly likely to the extent that securities lending by the Fed affects $\tilde{S}$ due to downward sloping borrowing demand. Aggregate dealer borrowing as a fraction of $Q_{\max}$ is thus likely to be a continuously increasing function of $\tilde{S}$ for values of $\tilde{S}$ near $F_{\min}$, rather than, as in Eq. (6), a discontinuously increasing function of $\tilde{S}$ at $\tilde{S} = F_{\min}$.

5.4. A borrowings model

We estimate the behavior of the borrowing ratio using a two-sided censored Tobit regression model (Greene, 1997, Chapter 20; Nakamura and Nakamura, 1983; Rosett and Nelson, 1975). This model is used because while transaction costs and other market frictions are likely to cause κ to have values other than zero and one, the observed borrowing ratio is nevertheless bounded between zero and one. The model is:

$$\kappa = \begin{cases} 0 & \text{if } \kappa^* < 0, \\ \kappa^* & \text{if } 0 < \kappa^* < 1, \\ 1 & \text{if } \kappa^* > 1 \end{cases} \tag{7a}$$

where:

$$\kappa^* = \gamma_0 + \gamma_1 \cdot \big(\tilde{S} - F_{\min}\big) + \tilde{\varepsilon}, \quad \tilde{\varepsilon} \sim N\big(0, \sigma_\varepsilon^2\big). \tag{7b}$$

Recalling that $\tilde{S} = S + \xi$ (where S is the 10:00 a.m. specialness spread), we can write the equation for κ^* as:

$$\kappa^* = \gamma_0 + \gamma_1 \cdot (S - F_{\min}) + \varepsilon, \quad \varepsilon \sim N\big(0, \varphi^2\big). \tag{7c}$$

where $\varepsilon = \gamma_1 \cdot \xi + \tilde{\varepsilon}$ and $\varphi^2 = \gamma_1^2 \cdot \omega^2 + \sigma_\varepsilon^2$.[18] We expect $\gamma_1 > 0$, so that a wider specialness spread is associated with greater borrowing from the Fed, and $0 < \gamma_0 < 1$, so that dealers borrow some but not all of the maximum amount possible when the specialness spread equals the minimum loan fee. The specialness spread at which the expected value of the borrowing ratio equals 50% is the value of S that satisfies the equation $\gamma_0 + \gamma_1 \cdot (S - F_{\min}) = 0.5$, or $S_{50\%} = F_{\min} + (0.5 - \gamma_0)/\gamma_1$.

Table 4 presents estimates of γ_0 and γ_1. As expected, $\hat{\gamma}_1$ is positive and highly significant, showing that the borrowing ratio increases with a security's specialness spread. This relationship is also evident from Fig. 2, which plots the expected borrowing ratio and the average actual borrowing ratio against the difference between the specialness spread and the minimum loan fee.[19]

Table 4
Tobit model estimates of the borrowing ratio

γ_0	γ_1	φ	$S_{50\%} - F_{\min}$	N
0.105	0.987	0.652	0.400	4791
(0.019)	(0.028)			
[<0.001]	[<0.001]			

Note: The table reports Tobit model estimates of the borrowing ratio in a Federal Reserve securities loan auction. The borrowing ratio, κ, is the ratio of the quantity of a security borrowed to the maximum amount of the security that could be borrowed with the observed borrowing ratio bounded between zero and one:

$$\kappa = \begin{cases} 0 & \text{if } \kappa^* < 0, \\ \kappa^* & \text{if } 0 < \kappa^* < 1, \\ 1 & \text{if } \kappa^* > 1. \end{cases}$$

The exogenous variable is the difference between the security's 10:00 a.m. specialness spread (in percent), S, and the Fed's minimum loan fee (in percent), $F_{\min}$, so that:

$$\kappa^* = \gamma_0 + \gamma_1 \cdot (S - F_{\min}) + \varepsilon, \quad \varepsilon \sim N\big(0, \varphi^2\big).$$

Standard errors of estimates are in parentheses and p-values on the null hypothesis that a coefficient is zero are in brackets. The specialness spread at which the expected value of the borrowing ratio is 50% is the value of S that satisfies the equation $\gamma_0 + \gamma_1 \cdot (S - F_{\min}) = 0.5$, or $S_{50\%} = F_{\min} + (0.5 - \gamma_0)/\gamma_1$, so that $S_{50\%} - F_{\min} = (0.5 - \gamma_0)/\gamma_1$.

[18] Estimating γ_0 and γ_1 with S on the right-hand side, as in Eq. (7c), is less efficient than estimating the coefficients with $\tilde{S}$ on the right-hand side, as in Eq. (7b), but does not result in an errors-in-variables bias because ε, the noise term in Eq. (7c), is not correlated with S, the 10:00 a.m. specialness spread. There would be an errors-in-variables bias if we had to use, e.g., a 2:00 p.m. specialness spread rather than a chronologically earlier observation of that spread.

[19] Following Greene (1997, pp. 960–961) and Johnson et al. (1994, p. 156), the expected censored borrowing ratio conditional on $S - F_{\min}$ is:

$$E[\kappa \mid S - F_{\min}] = \left\{ \gamma_0 + \gamma_1 \cdot (S - F_{\min}) + \frac{n\big(\frac{-\gamma_0 - \gamma_1 \cdot (S - F_{\min})}{\varphi}\big) - n\big(\frac{1 - \gamma_0 - \gamma_1 \cdot (S - F_{\min})}{\varphi}\big)}{N\big(\frac{1 - \gamma_0 - \gamma_1 \cdot (S - F_{\min})}{\varphi}\big) - N\big(\frac{-\gamma_0 - \gamma_1 \cdot (S - F_{\min})}{\varphi}\big)} \varphi \right\}$$

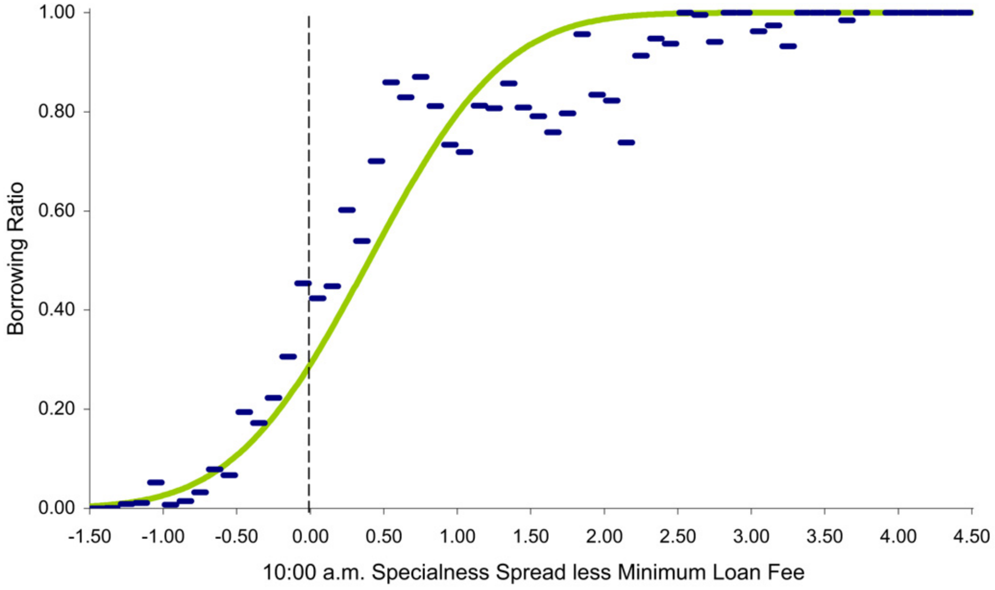

Fig. 2. Expected censored and average actual borrowing ratio. The figure plots the expected censored and average actual borrowing ratio in a Federal Reserve securities loan auction against the difference between the specialness spread for a security at 10:00 a.m. (measured in percent) and the Fed's minimum loan fee (also measured in percent). The borrowing ratio is the ratio of the quantity borrowed to the maximum amount that could be borrowed. The observed borrowing ratio is censored below zero and above one. The average actual borrowing ratio is estimated for each 10 basis point interval, inclusive of observations at the lower boundary of the interval.

Also as expected, $\hat{\gamma}_0$ is between zero and one and significantly different from both, showing that dealers borrow some but not all of the maximum amount possible when the specialness spread equals the minimum loan fee. Evidence on the quantity of securities borrowed thus reinforces the earlier conclusion that dealer participation in the Fed's auctions is reasonably consistent with the law of one price.

However, there is a tendency for dealers to not borrow the maximum possible amount of a security from the Fed when the specialness spread exceeds the minimum loan fee. The expected value of the borrowing ratio is 50% at a specialness spread 40 basis points greater than the minimum loan fee ($S_{50\%} = F_{\min} + 0.40$). This result is consistent with the idea that transaction costs and the relatively late hour of the Fed's securities loan auctions increase the riskiness and decrease the profitability of borrowing securities from the Fed for re-lending in the private market. Other possible explanations are most relevant in conjunction with the programmatic restrictions on dealer borrowing and are discussed in Section 6.

$$\times\left\{N\left(\frac{1-\gamma_0-\gamma_1\cdot(S-F_{\min})}{\varphi}\right)-N\left(\frac{-\gamma_0-\gamma_1\cdot(S-F_{\min})}{\varphi}\right)\right\}$$
$$+\left\{1-N\left(\frac{1-\gamma_0-\gamma_1\cdot(S-F_{\min})}{\varphi}\right)\right\}$$

where $n(\bullet)$ is the standard normal probability density function and $N(\bullet)$ is the standard normal cumulative density function.

Dealers' tendency to not borrow the maximum amount of securities from the Fed when specialness spreads exceed the minimum loan fee may seem at odds with dealers' unusually high propensity to borrow at least some quantity of securities when specialness spreads are less than the minimum loan fee. The results can be reconciled if one realizes that borrowings often occur in small quantities, and that such small-quantity borrowings are more common when specialness spreads are narrow. In particular, late-appearing borrowing demands and certainty of delivery can lead dealers to borrow small quantities of securities from the Fed that appear cheaper to borrow in the private market, explaining dealers' high propensity to borrow such securities, while having little effect in the quantity borrowed analysis. Conversely, the costs and riskiness of borrowing from the Fed for re-lending in the private market can explain the tendency of dealers to not borrow the maximum amount of securities that appear more expensive to borrow in the private market, while having little effect in the borrowing incidence analysis.

5.5. Auction loan fee

We conjecture that a security's specialness spread in the private market is also the proximate determinant of the average auction loan fee paid to borrow the issue from the Fed. More specifically, we hypothesize that, in the absence of transaction costs and other market frictions, a security's average auction loan fee will equal its specialness spread if the spread exceeds the Fed's minimum loan fee. If the specialness spread is less than the minimum loan fee, then we hypothesize that the average auction loan fee will equal the minimum loan fee.

To express our hypothesis in an analytical form, let F denote the average auction loan fee for a particular security on a given day. Ignoring transaction costs and other market frictions, the law of one price suggests that F should depend on $\tilde{S}$ and $F_{\min}$ as:

$$F = \begin{cases} \tilde{S} & \text{if } \tilde{S} > F_{\min}, \\ \text{unobserved} & \text{if } \tilde{S} < F_{\min}. \end{cases} \tag{8}$$

F is unobserved if $\tilde{S} < F_{\min}$ because, in the absence of market frictions, dealers should not borrow a security from the Fed if the security's specialness spread is less than the minimum loan fee.

As shown earlier, however, dealers sometimes borrow securities from the Fed when specialness spreads are less than the minimum loan fee. We allow for this possibility by modeling *observed* auction loan fees as:

$$F = \begin{cases} \tilde{S} & \text{if } \tilde{S} > F_{\min}, \\ F_{\min} & \text{if } \tilde{S} < F_{\min} \end{cases} \tag{9}$$

so that $F = F_{\min}$ if $\tilde{S} < F_{\min}$ and a security is borrowed. (The equation is not intended to suggest that a security will *necessarily* be borrowed if $\tilde{S} < F_{\min}$.)

Equation (9) is equivalent to the Tobit model:

$$F - F_{\min} = \begin{cases} 0 & \text{if } F^* - F_{\min} < 0, \\ F^* - F_{\min} & \text{if } F^* - F_{\min} > 0 \end{cases} \tag{10a}$$

where:

$$F^* - F_{\min} = \delta_0 + \delta_1 \cdot (\tilde{S} - F_{\min}) + \tilde{\eta}, \quad \tilde{\eta} \sim N(0, \sigma_\eta^2) \tag{10b}$$

for the special case when $\delta_0 = 0$, $\delta_1 = 1$, and σ_η is negligible.[20] Substituting $S + \xi$ for $\tilde{S}$ gives:

$$F^* - F_{\min} = \delta_0 + \delta_1 \cdot (S - F_{\min}) + \eta, \quad \eta \sim N(0, \phi^2) \tag{10c}$$

where $\eta = \delta_1 \cdot \xi + \tilde{\eta}$ and $\phi^2 = \delta_1^2 \cdot \omega^2 + \sigma_\eta^2$. We expect $\delta_1 = 1$, so that the average auction loan fee rises one-for-one with the specialness spread, and $\delta_0 = 0$, so that the average auction loan fee equals the minimum loan fee when the specialness spread equals the minimum loan fee.

Table 5 presents estimates of δ_0 and δ_1. As expected, $\hat{\delta}_1$ is positive and significantly different from zero, showing that the average auction loan fee increases with a security's specialness spread. This relationship is also evident from Fig. 3, which plots the expected censored loan fee less the minimum loan fee and the average actual auction loan fee less the minimum loan fee against the specialness spread less the minimum loan fee.[21] Evidence on auction loan fees thus broadly supports the earlier conclusions that dealer participation in the Fed's auctions is reasonably consistent with the law of one price.

However, while $\hat{\delta}_1$ is significantly greater than zero, it is also significantly less than one. Its value of 0.83 implies that the expected value of the uncensored loan fee rises about 8 basis points for every 10 basis point increase in the specialness spread. Moreover, $\hat{\delta}_0$ is significantly greater than zero. Its value of 0.05 implies that the expected value of the uncensored loan fee is about 5 basis points higher than the minimum loan fee when the specialness spread equals the minimum

Table 5
Tobit model estimates of the auction loan fee

δ_0	δ_1	ϕ	N
0.052	0.832	0.587	1176
(0.021)	(0.016)		
[0.013]	[<0.001]		

Note: The table reports Tobit model estimates of the difference between the average auction loan fee (in percent), F, and the minimum loan fee (in percent), $F_{\min}$, in a Federal Reserve securities loan auction. The difference is censored below zero:

$$F - F_{\min} = \begin{cases} 0 & \text{if } F^* - F_{\min} < 0, \\ F^* - F_{\min} & \text{if } F^* - F_{\min} > 0. \end{cases}$$

The exogenous variable is the difference between the security's 10:00 a.m. specialness spread (in percent), S, and $F_{\min}$, so that:

$$F^* - F_{\min} = \delta_0 + \delta_1 \cdot (S - F_{\min}) + \eta, \quad \eta \sim N(0, \phi^2).$$

Standard errors of estimates are in parentheses and p-values on the null hypotheses that δ_0 is zero and δ_1 is one are in brackets.

[20] If $\delta_0 = 0$, $\delta_1 = 1$, and σ_η is negligible, then, from Eq. (10b), $F^* - F_{\min} = \tilde{S} - F_{\min}$, i.e., $F^* = \tilde{S}$, in which case, from Eq. (10a), $F = F_{\min}$ if $\tilde{S} < F_{\min}$ and $F = \tilde{S}$ if $\tilde{S} > F_{\min}$.

[21] Following Greene (1997, pp. 960–961), the expected value of the censored difference between the auction loan fee and the minimum loan fee, conditional on $S - F_{\min}$, is:

$$E[F - F_{\min} \mid S - F_{\min}] = \left\{ \delta_0 + \delta_1 \cdot (S - F_{\min}) + \frac{n(\frac{-\delta_0 - \delta_1 \cdot (S - F_{\min})}{\phi})}{1 - N(\frac{-\delta_0 - \delta_1 \cdot (S - F_{\min})}{\phi})} \phi \right\} \times \left\{ 1 - N\left(\frac{-\delta_0 - \delta_1 \cdot (S - F_{\min})}{\phi} \right) \right\}.$$

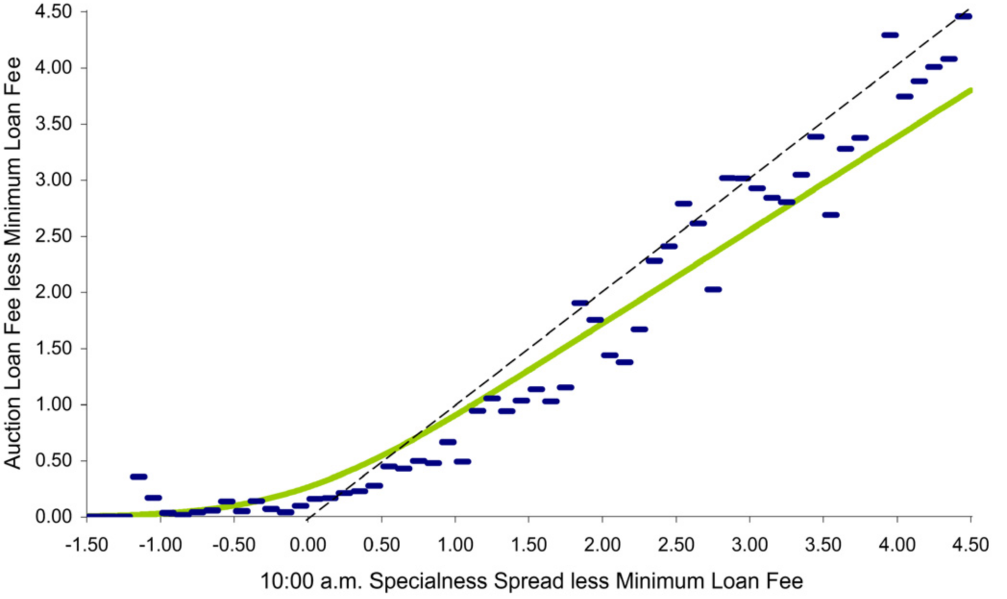

Fig. 3. Expected censored auction loan fee less the minimum loan fee and average actual auction loan fee less the minimum loan fee. The figure plots the expected censored auction loan fee less the minimum loan fee and the average actual auction loan fee less the minimum loan fee against the difference between the specialness spread for a security at 10:00 a.m. and the minimum loan fee. All variables are measured in percent. The observed difference between the auction loan fee and the minimum loan fee is censored below zero. The average actual auction loan fee is estimated for each 10 basis point interval, inclusive of observations at the lower boundary of the interval.

loan fee. Taken together, the results imply that auction loan fees tend to be less than specialness spreads when such spreads are more than about 30 basis points greater than the minimum loan fee.

Our results raise the question as to why dealers are not willing to pay more to borrow deeply special securities from the Fed for re-lending in the private market. Transaction costs and the relatively late hour of the Fed's auctions offer a partial explanation, as discussed earlier, because they decrease the expected profitability and increase the risk of such transactions. An additional reason, explored in the next section, is that programmatic restrictions on dealer borrowing limit the competitiveness of some auctions, enabling dealers to shade their bids.

6. Dealer behavior in less competitive and noncompetitive auctions

As noted earlier, dealers are limited to borrowing a specified quantity of any given security from the Fed. Moreover, the Fed limits what it will lend to a percentage of its holdings. While the latter constraint is binding more often than the former constraint, there are occasions when the reverse is true. That is, there are auctions where every dealer can borrow up to its limit without exhausting what the Fed has available to lend. This limitation on dealer borrowing has important implications for auction competitiveness and dealer behavior.

To examine the effects of the dealer borrowing limit, let $L_{\max}$ denote the maximum amount of a security that the Fed can lend. $L_{\max}$ is computed as the product of the maximum fraction of a

SOMA position that can be lent (Table 1, Panel B) and the size of the SOMA position,[22] rounded down to the nearest million. Let $B_{\max}$ denote the maximum amount that dealers in aggregate can borrow. $B_{\max}$ is computed as the product of the maximum amount of a security that a single dealer can borrow (Table 1, Panel C) and the number of primary dealers.[23] If $L_{\max} > B_{\max}$, then the maximum amount of a security that can be borrowed is determined by the dealer borrowing limit rather than the Fed lending limit and the auction is noncompetitive. Note that all of the information needed to calculate $L_{\max}$ and $B_{\max}$ is publicly available in advance of an auction.

On March 12, 2002, for example, the Fed owned \$6.7 billion of the on-the-run 2-year note, the 3% note of February 29, 2004. The maximum fraction of a SOMA position that could be lent on this date was 45%, so the Fed could lend up to \$3.0 billion of the note (i.e., $L_{\max} =$ \$3.0 billion). At the time, there were 24 primary dealers. As each dealer could borrow up to \$100 million of a given security, dealers in aggregate could borrow up to \$2.4 billion of the note (i.e., $B_{\max} =$ \$2.4 billion). Since the quantity available for lending exceeded the quantity that dealers in aggregate could borrow (i.e., $L_{\max} > B_{\max}$), the auction was noncompetitive. Every dealer could bid the minimum loan fee for its maximum possible allocation of \$100 million and be certain that its bid would be accepted.

Noncompetitive auctions are not unusual. We identify 383 instances in our sample of 4791 auctions where the limitation on what the Fed had available to lend exceeded the limitation on what dealers in aggregate could borrow (i.e., $L_{\max} > B_{\max}$). At least one dealer borrowed securities in 45 of these auctions.[24] Moreover, there are many other auctions in our sample where the limitation on what the Fed had available to lend was only slightly or somewhat less than the limitation on what dealers could borrow. The dealer borrowing limit may effectively be constraining in such cases if, for example, there are some dealers who do not regularly borrow securities from the Fed regardless of market conditions.

6.1. Implications for the quantity borrowed

The limitation on dealer borrowing can help explain why dealers tend to borrow less than the maximum amount of securities when specialness spreads are greater than the minimum loan fee. In cases where the maximum is constrained by the amount dealers can borrow, *every* dealer would have to borrow the maximum per dealer amount to reach the aggregate maximum. In practice, however, some dealers may not participate in a given auction even when a security is deeply special. On March 12, 2002, for example, dealers borrowed only \$1.816 billion of the on-the-run 2-year note (\$584 million less than they could have borrowed), even though the note's specialness spread at 10:00 a.m. was 48 basis points greater than the Fed's minimum loan fee.

The importance of the dealer borrowing limit for the quantity of securities borrowed from the Fed is demonstrated through a simple modification of our borrowing ratio model. Let H denote the ratio of the maximum amount that the Fed can lend ($L_{\max}$) to the maximum amount that dealers can borrow ($B_{\max}$):

$$H = L_{\max}/B_{\max}. \tag{11}$$

[22] SOMA positions in the notes in our sample range from \$0.75 billion to \$7.87 billion. SOMA positions are posted weekly to the New York Fed's website at http://www.newyorkfed.org/markets/soma/sysopen_accholdings.html.

[23] The number of dealers over our sample period ranges from 22 to 30. The dealers are listed on the New York Fed's website at http://www.newyorkfed.org/markets/pridealers_current.html.

[24] These 45 auctions are included in the 1176 observations used to estimate δ_0 and δ_1 in Eq. (10c). Excluding these auctions has no material effect on the results reported in Table 5.

We modify Eq. (7c) to allow κ^*, the observed borrowing ratio, to depend on H:

$$\kappa^* = \gamma_0 + \gamma_1 \cdot (S - F_{\min}) + \gamma_2 \cdot H + \varepsilon, \quad \varepsilon \sim N(0, \varphi^2). \tag{12}$$

We expect $0 < \gamma_0 < 1$, and $\gamma_1 > 0$, as before, and we also expect $\gamma_2 < 0$, so that the borrowing ratio decreases as the Fed lending limit increases relative to the dealer borrowing limit.[25]

Table 6 presents estimates of γ_0, γ_1, and γ_2. As before, $\hat{\gamma}_0$ is between zero and one and significantly different from both and $\hat{\gamma}_1$ is positive and highly significant. Moreover, as expected, $\hat{\gamma}_2$ is negative and highly significant, showing that the borrowing ratio decreases as the Fed lending limit increases relative to the dealer borrowing limit. The limitation on what a dealer can borrow of a security can thus help explain why aggregate dealer borrowing is often less than expected. That is, if one or more dealers does not fully participate in an auction for whatever reason, the borrowing limitation can prevent other dealers from stepping in to bring aggregate dealer borrowing to its limit.

The effects of the borrowing limit are particularly revealing of dealer behavior when auctions are noncompetitive and specialness spreads exceed the minimum loan fee. As shown in Table 7, specialness spreads at 10:00 a.m. exceeded the Fed's minimum loan fee in 38 of the 383 noncompetitive auctions in our sample (i.e., auctions for which $H > 1$). However, the highest borrowing ratio across the 38 auctions was only 76% (from our March 12, 2002 example). This means that some dealers passed up opportunities for riskless profits in each of the 38 auctions. In particular, dealers could have lent securities in the private market in the morning at a fee greater than the Fed's minimum loan fee knowing that they could offset these loans in the Fed's noontime auctions at the minimum fee.

Table 6
Extended Tobit model estimates of the borrowing ratio

γ_0	γ_1	γ_2	φ	N
0.316	0.960	−0.387	0.638	4791
(0.034)	(0.027)	(0.057)		
[<0.001]	[<0.001]	[<0.001]		

Note: The table reports Tobit model estimates of the borrowing ratio in a Federal Reserve securities loan auction. The borrowing ratio, κ, is the ratio of the quantity borrowed of a security to the maximum amount of the security that could be borrowed with the observed borrowing ratio bounded between zero and one:

$$\kappa = \begin{cases} 0 & \text{if } \kappa^* < 0, \\ \kappa^* & \text{if } 0 < \kappa^* < 1, \\ 1 & \text{if } \kappa^* > 1. \end{cases}$$

The first exogenous variable is the difference between the security's 10:00 a.m. specialness spread (in percent), S, and the Fed's minimum loan fee (in percent), $F_{\min}$, and the second exogenous variable is the ratio of what the Fed has available to lend to what dealers in aggregate can borrow, H, so that:

$$\kappa^* = \gamma_0 + \gamma_1 \cdot (S - F_{\min}) + \gamma_2 \cdot H + \varepsilon, \quad \varepsilon \sim N(0, \varphi^2).$$

Standard errors of estimates are in parentheses and p-values on the null hypothesis that a coefficient is zero are in brackets.

[25] We also tested a more complicated model that interacts H with $(S - F_{\min})$ and find support for the hypothesis that the borrowing ratio increases with $(S - F_{\min})$ at a decreasing rate as H increases. However, our more parsimonious model fits the data nearly as well.

Table 7
Noncompetitive auctions

	$S > F_{min}$ ($n = 38$)	$S < F_{min}$ ($n = 345$)
At least one dealer borrowed a security ($n = 69$)	36 (35 with $F > F_{min}$, 1 with $F = F_{min}$)	33 (10 with $F > F_{min}$, 23 with $F = F_{min}$)
No dealer borrowed a security ($n = 314$)	2	312

Note: The table categorizes the 383 securities loan auctions in our data set that were noncompetitive because the Federal Reserve had more securities available to lend than dealers in aggregate could borrow. The noncompetitive auctions are partitioned into those where a security's 10:00 a.m. specialness spread, S, was greater than or less than the Fed's minimum loan fee, F_{min}, and those where at least one dealer did, or did not, borrow a security. In auctions where at least one dealer borrowed a security, the auctions are further partitioned into those where the average auction loan fee, F, equaled or exceeded F_{min}.

Why might dealers pass up these riskless profit opportunities? One possibility is that the aggregate borrowing limit is sometimes binding for one or more dealers, limiting the ability of dealers to take advantage of these opportunities. We cannot evaluate this conjecture directly since we do not have data on the bidding or borrowings of individual dealers. However, even if the aggregate limit were sometimes binding, one would think that dealers would choose to borrow up to the per-security limit in auctions in which riskless profit opportunities were available and curtail their bidding in competitive auctions on the same day. Only in cases in which there were opportunities for riskless profits in multiple securities on the same day would we expect to see dealers limiting their bidding in such auctions and such cases are almost certainly rare or nonexistent during our sample period.[26]

An alternative explanation is that some dealers are reluctant to borrow securities from the Fed for re-lending in the private market because they think the Fed discourages such borrowing or subjects borrowing dealers to unusual scrutiny. As noted earlier, the current program does not preclude borrowing for certain purposes. However, it is possible that this perception exists because of the Fed's earlier requirement that a dealer certify that it was borrowing to replace securities that a seller had failed to deliver. Such a belief may have persisted because of the program's stated objective of being a secondary source of securities to promote the smooth clearing of Treasury securities.[27]

A third possibility is that some dealers limit their specials market trading to supporting other parts of their businesses and have not made the investment necessary to become active traders. Per-dealer profits over the 38 noncompetitive auctions of securities with specialness spreads greater than the minimum loan fee were at most \$89 thousand. The profits are estimated as the sum of the differences between the specialness spreads and the minimum loan fee, multiplied by the per-security borrowing limit for a dealer, taking into account the number of days the loans

[26] Of the 38 instances in our sample of noncompetitive auctions of securities with specialness spreads greater than the minimum loan fee, at most two occurred on the same day. Our sample is limited to on-the-run and first off-the-run notes, which tend to be most special, but it is possible that there were instances involving other securities during our sample period.

[27] See Federal Reserve Bank of New York (1999) and the current description of the program posted at the New York Fed's website at: http://www.newyorkfed.org/markets/securitieslending.html.

would have been outstanding (usually one).[28] A dealer not in the business of actively borrowing and lending securities might not find such profits sufficient to undertake an activity it does not normally engage in.

Still another explanation, supported by evidence on the auction loan fee and discussed in the next section, is that some dealers do not realize that certain auctions are noncompetitive.

6.2. Implications for the auction loan fee

The limitation on dealer borrowing also has implications for the fees bid by dealers in the Fed's securities loan auctions. At one extreme, when the Fed lending limit is low relative to the dealer borrowing limit (i.e., $H \approx 0$), competition should force dealers to make bids quite close to the private market cost of borrowing a security. However, when the quantity the Fed can lend exceeds what dealers in aggregate can borrow (i.e., $H > 1$), an auction is noncompetitive and dealers should bid the minimum loan fee. In cases where H is near but somewhat below one, limited competition might enable dealers to shade their bids below the private market cost of borrowing a security and yet force them to bid more than the minimum loan fee.

The importance of the dealer borrowing limit for auction loan fees is demonstrated through a modified version of our auction loan fee model. We modify Eq. (10c) to allow the uncensored auction loan fee to depend on H:

$$F^* - F_{\min} = \delta_0 + \delta_1(H) \cdot (S - F_{\min}) + \eta \tag{13}$$

where $\delta_1(H)$ declines from one to zero as H increases from zero to one. When $H \approx 0$, $\delta_1(H) \approx 1$, and the auction loan fee is expected to increase one-for-one with the specialness spread. When $H > 1$, $\delta_1(H) = 0$, and the auction loan fee is expected to be independent of the specialness spread. At intermediate values of H, $0 < \delta_1(H) < 1$, and the auction loan fee is expected to increase with the specialness spread at a less than a one-for-one rate.

We examine a piecewise-constant representation of the $\delta_1(H)$ function. Let $D[H; a, b]$ indicate whether H is greater than a and less than b:

$$D[H; a, b] = \begin{cases} 1 & \text{if } a < H < b, \\ 0 & \text{otherwise.} \end{cases} \tag{14}$$

We can express $\delta_1(H)$ as:

$$\begin{aligned} \delta_1(H) = {} & \delta_{1,a} \cdot D[H; 0.00, 0.25] + \delta_{1,b} \cdot D[H; 0.25, 0.50] + \delta_{1,c} \cdot D[H; 0.50, 0.75] \\ & + \delta_{1,d} \cdot D[H; 0.75, 1.00] + \delta_{1,e} \cdot D[H; 1.00, \infty]. \end{aligned} \tag{15}$$

Substituting the expression for $\delta_1(H)$ in Eq. (15) into Eq. (13) gives the loan fee model:

$$F - F_{\min} = \begin{cases} 0 & \text{if } F^* - F_{\min} < 0, \\ F^* - F_{\min} & \text{if } F^* - F_{\min} > 0 \end{cases} \tag{16a}$$

where:

$$\begin{aligned} & F^* - F_{\min} \\ & \quad = \delta_0 + \delta_{1,a} \cdot D[H; 0.00, 0.25] \cdot (S - F_{\min}) + \delta_{1,b} \cdot D[H; 0.25, 0.50] \cdot (S - F_{\min}) \end{aligned}$$

[28] For example, per-dealer profits from borrowing and re-lending the on-the-run 2-year note on Tuesday, March 12, 2002 are estimated as \$1333.33 (\$1333.33 = (1.48% specialness spread − 1% minimum loan fee) ∗ \$100 million borrowing limit ∗ 1 day/360 days).

$$+\delta_{1,c}\cdot D[H;0.50,0.75]\cdot(S-F_{\min})+\delta_{1,d}\cdot D[H;0.75,1.00]\cdot(S-F_{\min})$$
$$+\delta_{1,e}\cdot D[H;1.00,\infty]\cdot(S-F_{\min})+\eta. \tag{16b}$$

We expect $\delta_{1,a}=1$, $\delta_{1,e}=0$, and $\delta_{1,a}>\delta_{1,b}>\delta_{1,c}>\delta_{1,d}>\delta_{1,e}$.

Table 8 shows estimates of $\delta_{1,a}$, $\delta_{1,b}$, $\delta_{1,c}$, $\delta_{1,d}$, and $\delta_{1,e}$. The results correspond roughly to expectations, with $\hat{\delta}_{1,a}$ close to one, and larger than $\hat{\delta}_1$ from Table 5, albeit still significantly less than one statistically. Moreover, $\hat{\delta}_{1,a}$, $\hat{\delta}_{1,b}$, $\hat{\delta}_{1,c}$, $\hat{\delta}_{1,d}$, and $\hat{\delta}_{1,e}$ generally decline in the expected fashion (although $\hat{\delta}_{1,d}$ is slightly less than $\hat{\delta}_{1,e}$), with both $\hat{\delta}_{1,d}$ and $\hat{\delta}_{1,e}$ far below one, and $\hat{\delta}_{1,d}$ (but not $\hat{\delta}_{1,e}$) insignificantly different from zero. When H is less than 0.25, auction loan fees tend to be close to the private market costs of borrowing securities, although there is still a tendency for auction loan fees to be lower for securities that are deeply special (perhaps due to transaction costs and the late hour of the Fed's auctions). At higher levels of H, there is strong evidence that dealers respond by shading their bids below the specialness spread in the private market. When H is greater than 0.75, auction loan fees are essentially independent of the specialness spread.[29]

The estimated value of $\delta_{1,e}$ deserves special discussion. The observations that go into this estimate have a value of $H>1$, so that every dealer could have bid the minimum loan fee and still borrowed up to its limit. Nonetheless, $\hat{\delta}_{1,e}$ is positive and significantly greater than zero. In fact, as shown in Table 7, dealers paid an average loan fee greater than the minimum loan fee in 35 of the 36 noncompetitive auctions in which dealers borrowed securities and the specialness

Table 8
Extended Tobit model estimates of the auction loan fee

δ_0	$\delta_{1,a}$	$\delta_{1,b}$	$\delta_{1,c}$	$\delta_{1,d}$	$\delta_{1,e}$	ϕ	N
0.062	0.925	0.876	0.614	0.251	0.284	0.547	1176
(0.020)	(0.023)	(0.021)	(0.028)	(0.182)	(0.117)		
[0.002]	[<0.001]	[<0.001]	[<0.001]	[0.167]	[0.015]		

Note: The table reports Tobit model estimates of the difference between the average auction loan fee (in percent), F, and the minimum loan fee (in percent), $F_{\min}$, in a Federal Reserve securities loan auction. The difference is censored below zero:

$$F-F_{\min}=\begin{cases}0 & \text{if } F^*-F_{\min}<0,\\ F^*-F_{\min} & \text{if } F^*-F_{\min}>0.\end{cases}$$

The exogenous variable is the difference between the security's 10:00 a.m. specialness spread (in percent), S, and $F_{\min}$. The coefficient on the exogenous variable is allowed to vary as a discrete function of the variable H, which is the ratio of the maximum amount the Fed can lend ($L_{\max}$) to the maximum amount that dealers in aggregate can borrow ($B_{\max}$): $H=L_{\max}/B_{\max}$. The dummy variable $D[H;a,b]$ is one if $a<H<b$ and zero otherwise, so that:

$$\begin{aligned}F^*-F_{\min}=\delta_0&+\delta_{1,a}\cdot D[H;0.00,0.25]\cdot(S-F_{\min})+\delta_{1,b}\cdot D[H;0.25,0.50]\cdot(S-F_{\min})\\&+\delta_{1,c}\cdot D[H;0.50,0.75]\cdot(S-F_{\min})+\delta_{1,d}\cdot D[H;0.75,1.00]\cdot(S-F_{\min})\\&+\delta_{1,e}\cdot D[H;1.00,\infty]\cdot(S-F_{\min})+\eta,\quad \eta\sim N(0,\phi^2).\end{aligned}$$

Standard errors of estimates are in parentheses and p-values on the null hypothesis that a coefficient is zero are in brackets.

[29] Consistent with these results, the highest value of H at which the maximum amount of securities was lent in our sample was 0.75. That is, ex post, every auction with a value of H greater than 0.75 was noncompetitive.

spread exceeded the minimum loan fee.[30] On March 12, 2002, for example, dealers paid an average auction loan fee of 1.17% for the on-the-run 2-year note, 17 basis points higher than the 1% minimum loan fee.

Why might dealers leave money on the table by overbidding in noncompetitive auctions? Transaction costs, the late hour of the Fed's auctions, the aggregate dealer borrowing limit, reluctance to borrow securities from the Fed, and not being in the business of actively borrowing and lending securities may explain why a dealer might not participate in an auction, but they cannot explain why a dealer would pay more than necessary to borrow securities. We think the evidence is compelling that some participating dealers are just not aware that certain auctions are noncompetitive, even though the information needed to make such determinations is publicly available in advance.[31]

Why might dealers not realize that certain auctions are noncompetitive? Some dealers may assume that all auctions are competitive without doing the calculations. In practice, only a small share of auctions is clearly noncompetitive. Moreover, the amount of overpayments—roughly $378 thousand over the 45 noncompetitive auctions in our sample in which dealers paid more than the minimum loan fee—is not huge. Overpayments equal the sum of the differences between the weighted average loan fees paid in the noncompetitive auctions and the minimum loan fee, multiplied by the amounts of the securities borrowed, taking into account the number of days the loans would have been outstanding (usually one).[32] It is therefore also possible that some dealers fully understand the Fed's program and yet decide that it is not worth the cost of informing themselves as to whether a particular auction is noncompetitive.

Our findings are related to those of Fleming and Garbade (2005) and Goldreich (2005), who document suboptimal bidding behavior by dealers in short-term Treasury bill auctions. Goldreich argues that such behavior can be explained by bounded rationality, whereby agents use heuristics to approximate an optimal action. Applied to the securities loan auctions, some dealers may have a heuristic of bidding based on private market prices, perhaps augmented by their experiences and loan fees in past auctions, without accounting for certain auctions being noncompetitive.

7. Conclusions

We find that dealer behavior in the Federal Reserve's securities loan auctions is generally consistent with the law of one price and that apparent violations can largely be explained by institutional differences between the Fed's program and the private market. Late-appearing borrowing demands and certainty of delivery can explain why dealers sometimes borrow securities from the Fed at prices higher than those in the private market. Conversely, transaction costs and the relatively late hour of the Fed's securities loan auctions limit the feasibility and attractiveness of borrowing from the Fed for re-lending in the private market and can thus explain why deal-

[30] As also shown in Table 7, dealers did not borrow any securities in two of the 38 noncompetitive auctions in which specialness spreads exceeded the minimum loan fee. Dealers borrowed securities in 33 of the 345 noncompetitive auctions in which the specialness spread was less than the minimum loan fee and paid an average fee greater than the minimum in 10 of these cases.

[31] Note that dealers' apparent lack of awareness of noncompetitive auctions has persisted over time. Average auction loan fees exceeded the minimum loan fee for the on-the-run 2-year note on each of the last 14 business days of April 2004 even though all of the auctions were noncompetitive.

[32] For example, the overpayment for the on-the-run 2-year note on Tuesday, March 12, 2002 was $8575.56 ($8575.56 = (1.17% weighted average loan fee − 1% minimum loan fee) ∗ $1.816 billion borrowed ∗ 1 day/360 days).

ers sometimes abstain from borrowing securities from the Fed at prices lower than those in the private market.

However, we also find evidence of suboptimal dealer behavior in auctions that are effectively noncompetitive. In such auctions, dealers regularly pass up riskless opportunities to borrow securities from the Fed for re-lending in the private market at a higher fee. Moreover, while dealers appear to shade their bids in noncompetitive auctions, they frequently pay more than the minimum fee necessary to borrow securities in such auctions. We consider various explanations and conclude that some dealers must not realize that certain auctions are noncompetitive, even though the information needed to discern this fact is publicly available in advance.

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