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ABSTRACT

Pre-Auction Inventory and Bidding Behavior—An Analysis of Canadian Treasury Auctions*

Many bidders enter the Government of Canada securities auctions with short or long pre-auction inventory. We find that bidding strategies and auction performance vary with pre-auction ownership structure. Short and long bidders bid higher average prices and demand larger quantities than do bidders with neutral pre-auction inventory. The effects of pre-auction ownership on bidder behavior vary with the auction cycle and with uncertainty. We argue that post-auction short squeeze does not explain the observed relation between securities prices and ownership structure.

JEL Classification: D44 and G10
Keywords: discriminatory auction, market power, ownership distribution, short squeeze and when-issued market

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1 Introduction

Many bidders in treasury auctions enter with a short or a long position in the security to be auctioned. Negative and positive pre-auction inventory is built in the when-issued market that precedes an auction of a new security, or in the secondary market that is in operation before the reopening auction of an existing security. Securities dealers with privileges on bidding in the auction are natural sellers before the auction as they can expect to cover a short inventory position in the auction. Investors are natural counter-parties in the pre-auction trading in that they can ensure delivery void of the uncertainty of the auction. In addition to liquidity-motivated transactions between securities dealers and customers, securities dealers can take speculative short and long positions and they can trade for risk management purposes. Trading before the auction is considered to be beneficial to all market participants. It enhances price discovery and improves risk sharing by stretching the distribution process.

Auction participants have incomplete information about the pre-auction inventory of the other bidders because transactions in the when-issued market or the secondary market are privy to the securities dealers and their customers. For practicality reasons, treasury securities are sold through sealed bidding, so the bidders do not know the competing bids either. As a result of these uncertainties, bidders with short pre-auction inventory may fall short after the auction in which case they must turn to bidders with long post-auction inventory to either borrow or purchase at terms that reflect the scarcity of the newly auctioned security. Standard economic arguments imply that the bids submitted in the auction reflect the opportunity cost of covering shortfall in the after market. In a perfect and competitive secondary market, purchasing securities in the auction or the after market is a matter of irrelevance. However, any market imperfection related to private information, imperfect risk sharing, or imperfect competition may induce bidders to alter their bidding strategies with the size of the pre-auction ownership position. The primary objective of our paper is to investigate how bidding strategies in treasury auctions vary with pre-auction ownership structure.

We analyze the bids in more than 1200 auctions of Government of Canada securities that are conducted by the Bank of Canada (as the fiscal agent of the Department of Finance Canada) from

October 1998 through 2011. For conformity with the literature, we refer to them as Canadian Treasury auctions. The auctions are carried out under the discriminatory format where winning bidders pay what they bid. The data set consists of the auction bids of the Government Securities Distributors and their pre-auction inventory positions. We report several new empirical regularities. *(i)* Bidders with negative pre-auction inventory bid higher prices and demand larger quantities than do bidders with neutral pre-auction inventory. Consider as an example an auction of a new one-year Treasury bill and a bidder with a pre-auction inventory of –25%. We estimate that the short bidder bids 2.7 price basis points above the average bid of a neutral bidder, and he demands the maximum allowed quantity of 25% of the awards. *(ii)* Bidders with positive pre-auction inventory aim at increasing their long inventory position. According to our estimation, in a reopening auction of a one-year Treasury bill, a bidder with a pre-auction inventory of +25% submit bids at an average premium of 1.1 price basis points above neutral bidders, and the long bidder demands about half the maximum allowed quantity of 12.5% of the awards. *(iii)* As a result of the more aggressive bidding of short and long bidders, there is less underpricing in auctions with aggregate inventory positions that are tilted in either direction. *(iv)* The effects of pre-auction ownership on bidding strategies weaken over the auction cycle, and they vary over time. The effects peak during the global financial crisis of 2008 when uncertainty is high.

The data set allows us to carry out a detailed investigation of whether the possibility of a post-auction short squeeze influences the auction bidding strategies. This investigation is our secondary objective. The post-auction securities ownership may end up in the hands of single securities dealer that can exercise market power over dealers with negative post-auction inventory. This situation is commonly referred to as a short squeeze situation, which can result in secondary market prices rising above their competitive level. A short squeeze can arise out of chance, for example, when the securities dealers collectively pre-sell more securities than their combined market share of the auction.[1] A short squeeze can also arise from outright market manipulation known as market

[1]There are examples of such auction outcomes in our data set. The Joint Report on the Government Securities Market (1992), Appendix B, pp. B-1–B-3 discusses situations that can be characterized as unintentional short squeezes. A related discussion can also be found on pp. 124–125 in the *Journal of Economic Perspectives* article by Bikhchandani and Huang (1993). The mispricing of the 30-year US Treasury bond in 1986 is a well-known example of a short squeeze that probably emerged by chance (Cornell and Shapiro (1989)).

corner. The Bank of Canada bidding rules are designed so that nobody can control more than 25% of the securities that are outstanding after the auction, i.e., the sum of previously issued securities and the auction awards.[2] The bidding rules may prevent market corner, but they do not necessarily rule out unintentional short squeezes.

Shortfalls are common in the Canadian Treasury market as more than one in every ten bidders with negative pre-auction inventory end up with negative post-auction inventory, and there are short squeeze situations. Most of the time, bidders with negative post-auction inventory can turn to multiple long bidders to cover the short inventory position, but in one of every forty auctions, a single long bidder controls residual supply. This leaves short bidders with the options to negotiate with the single long bidder, trade with customers, or borrow from the Bank of Canada. The relatively few short squeeze situations may be the outcome of aggressive bidding in the auctions: bidders with negative pre-auction inventory bid aggressively to avoid being squeezed, and long bidders submit high bids to establish a long post-auction ownership position to profit from a short squeeze. However, three observations speak against the short-squeeze hypothesis of aggressive bidding in the auctions. First, with the exception of a few auctions of new Treasury bill maturities, the single long bidder controls a small fraction of supply and an even smaller fraction of the outstanding stock, which means that short bidders are likely to escape the short squeeze situation through regular transactions with customers in the secondary market. Second, bidding of short and long bidders is especially aggressive in 2008, when the short-term interest rate drops below 1% and the profit potential from implementing a short squeeze reaches a sample-period minimum.[3] Third, the Bank of Canada established in 2002 its Securities-Lending Program where bidders can borrow securities to meet physical delivery. The lending facility has not been used in connection with the auctions.[4]

[2]The Bank of Canada revised its bidding rules in responses to incidences of short squeezes in the Canadian Treasury market (Bank of Canada (1998)). Before the revision, a bidder could acquire up to 33% of Treasury bill auctions and 20% of Treasury bond auctions regardless of his pre-auction inventory. The old bidding rules made market corner possible, and examples of market corners are mentioned in the Bank of Canada report.

[3]See Duffie (1996) for an analysis of special repo rates.

[4]The lending facility opens at the discretion of the Bank of Canada. The cost of borrowing is determined through a discriminatory auction. For Treasury bills, the minimum bid rate is the lower of 100 basis points and 50% of the Bank of Canada target rate and, for Treasury bonds, it is the lower of 150 basis points and 50% of the target rate. From 2010, the minimum bid rate is 25 basis points. Absent competition among securities dealers, the implied borrowing rate is less than the short-term interest rate.

Our paper is related to the literature that analyzes market corner and short squeeze in futures and treasury markets. Models of futures markets corner emanate from Kyle (1984) and Dunn and Spatt (1984), and extend through Jarrow (1992) and Cooper and Donaldson (1998). A real-world illustration is provided by the market corner of the UK bond futures market (Merrick, Naik, and Yadav (2005)). Noticeable work on treasury market corners include Chatterjea and Jarrow (1998) and Nyborg and Strebulaev (2004). These papers are inspired by the Salomon Brother's corner of the two-year Treasury note auction in May 1991.[5] Nyborg and Strebulaev (2004) analyze a mixed-strategy equilibrium where one short bidder, on average, bids aggressively to prevent being squeezed and one long bidder, now and then, bids aggressively to attempt a market corner. The model is stylized and leaves out important features of the Canadian Treasury markets such as the bidding limits, but the predicted bidding strategies of the short and the long bidders are consistent with observed auction bids.

Our paper is also related to the general literature that studies bidder behavior and performance of multi-unit auctions.[6] The investigation of bidding with pre-auction ownership makes our paper different. Several papers have studied the Canadian Treasury auctions previously. Lu and Yang (2003) investigate the relation between auction profits and bidder participation, Cao and Lu (2004) study bid revisions before the auction closes, and Hortaçsu and Sareen (2005) make inference about the value of order-flow information from another Bank of Canada regulation that separates dealer bids from customer bids. Subsequently, Hortaçsu and Kastl (2012) develop and estimate a model with private values within the same data set. Most recently, Armantier and Lafhel (2009) estimate a structural model that is used to rank auction formats in a counterfactual experiment. The data sets of the five papers partly overlap with our study, but none of them studies pre-auction inventory and bidder behavior.

The remainder of the paper is organized as follows: Section 2 provides institutional information from the Canadian Treasury market. In Section 3, we analyze bidding strategies with pre-auction ownership and, in Section 4, we investigate the bond ownership data for evidence of shortfalls and

[5] See, e.g., Joint Report on the Government Securities Market (1992), Jegadeesh (1993), and Jordan and Jordan (1996).

[6] E.g., Cammack (1991), Nyborg, Rydqvist, and Sundaresan (2002), Keloharju, Nyborg, and Rydqvist (2005)), and Goldreich (2007).

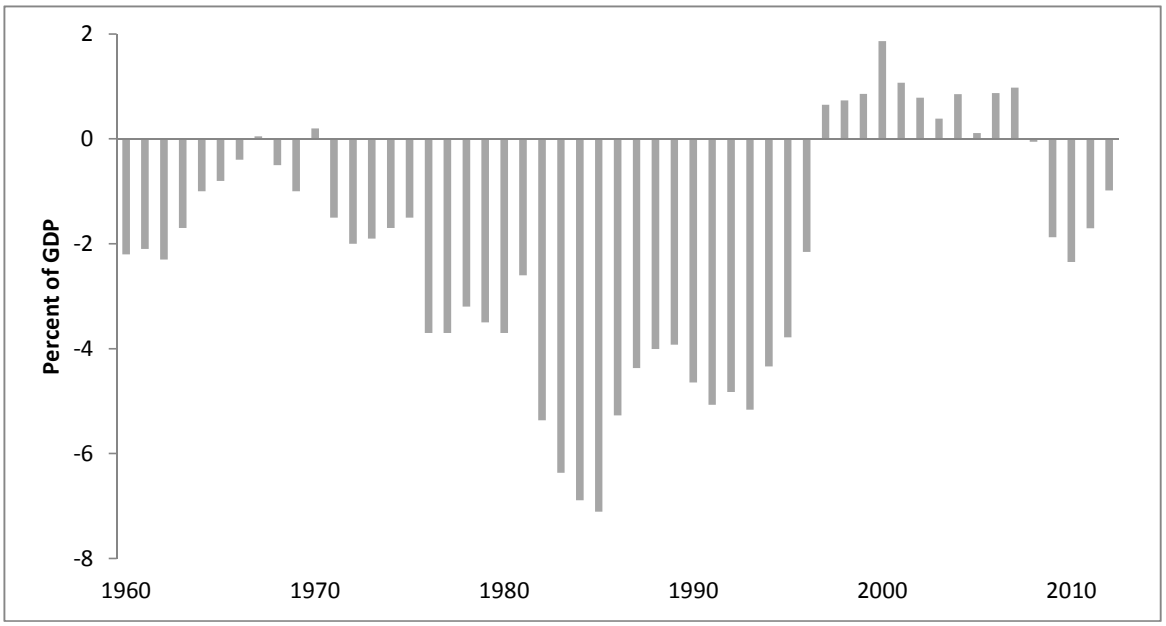
squeezes. Section 5 concludes the paper.

2 Institutional Background and Data

2.1 Canadian Treasury Market

The Government of Canada borrows money from the public to fund its budget deficit and to refinance its outstanding debt. Figure 1 plots the deficit as a percentage of GDP from 1960–2012. The Government budget is balanced in the 1960s and 2000s, and it is in deficit between. As a result of persistent budget deficits, Government of Canada debt grows from about 10% of GDP in the 1960s to 70% at its peak in the mid 1990s. It subsequently decreases to 25% of GDP as the budget turns into surplus.

Figure 1: Canadian Government Budget Deficit 1960-2012



This figure plots the annual surplus/deficit as a percentage of GDP. Source: *Worthwhile Canadian Initiative* and Statistics Canada.

Since the beginning of the 1990s, the Government of Canada sells nominal debt securities through auctions.[7] The Canadian Treasury auctions are sealed-bid and discriminatory. Bids are

[7]The two-year bond has been auctioned since 1983. Otherwise, in the past, Canadian Treasury securities were

submitted electronically in yields separated by three decimals for a minimum quantity multiple of one million Canadian dollars. From 1990–September 1998, bidders can submit any number of bids but, from October 1998, the maximum number of bids is seven. The Bank of Canada also permits non-competitive bids up to three million dollars of face value.[8] Non-competitive bids are awarded at the weighted-average winning price. The Bank of Canada first accepts all non-competitive bids and, then, accepts competitive bids in ascending order in terms of their yields (lowest to highest) until the issue is exhausted. Submission of competitive bids is restricted to Government Securities Distributors, which (from October 1998) are further divided into primary dealers and other distributors that we refer to as secondary dealers for convenience. Customers can also bid competitively, but they must route their bids through the dealers.

The Government of Canada issues Treasury bills and Treasury bonds. Treasury bills are zero-coupon securities with maturities of approximately three, six, and twelve months from issuance. Treasury bonds are long-term, non-callable, bullet securities that make semi-annual coupon payments. The bonds are labeled by their time to maturity at issuance, which is approximately two, three, five, ten, and 30 years.[9] The terms of the tender are announced one week in advance of the auction, which is held at 12:30 p.m. on the subsequent Tuesday (Treasury bills) or Wednesday (Treasury bonds). The awards are released shortly after the bid submission deadline. The settlement of the auction takes place two business days later for Treasury bills, while the time to settlement for Treasury bonds varies from two business days to one week or more. A when-issued market opens with the announcement of the terms of the tender, and it ends with the settlement of the auction awards. Secondary market trading begins on the auction settlement day. The when-issued market is in operation around both new and reopening auctions. Secondary market trading volume is comparable to trading of US Treasury debt with annualized turnover ratios between 1000

sold by commission or underwriting (Pellerin (2006)). For comparison, auctions have been used to sell US Treasury bills since 1929 and US Treasury notes and bonds since 1970.

[8]The current policy is up to three million dollars for their own account, and up to ten million dollars on behalf of customers with no single customer having more than five million from a securities dealer.

[9]This list is not exhaustive. Occasionally, the Government of Canada raises money for immediate needs by auctioning Treasury bills with maturities of less than 90 days referred to as cash management auctions. The Government of Canada also sells Real Return bonds with the coupon payment being adjusted for changes in the consumer price index. Treasury bills and nominal bonds are sold through discriminatory auctions. Real Return bonds are sold through uniform auctions.

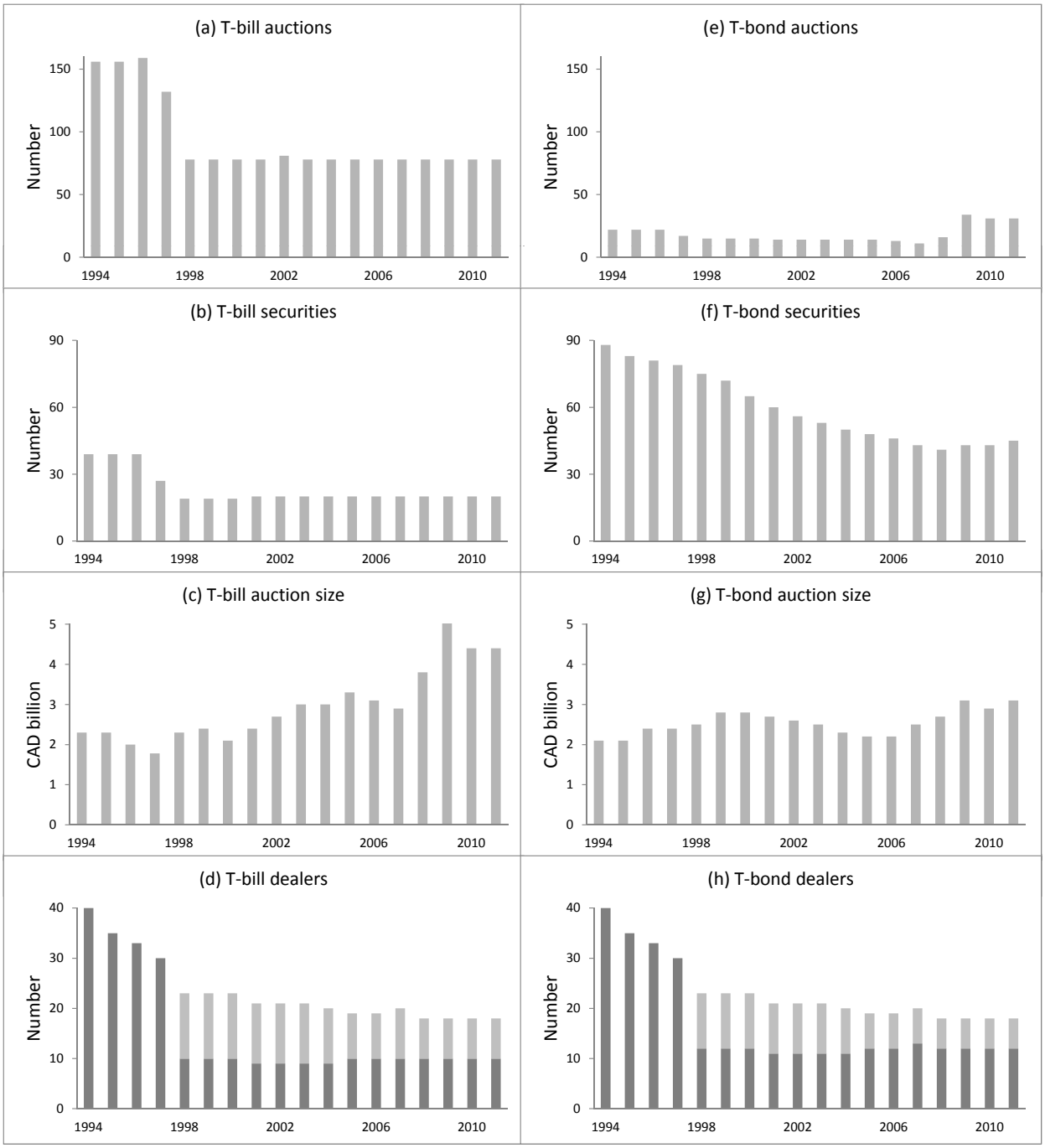
and 2000 per cent.[10]

In Figure 2, we summarize key features of the Canadian Treasury market. The Treasury bill market is displayed to the left and the Treasury bond market to the right. Three Treasury bill securities with three-, six, and twelve months to maturity are auctioned on the same day. In 1996–1998, the Bank of Canada switches from weekly to biweekly Treasury bill auctions. As a result, the number of Treasury bill auctions is cut in half from $3 \times 52 = 156$ to $3 \times 26 = 78$ auctions per year (Panel (a)). The lower auction frequency is a response to the reduced borrowing needs of the Government of Canada. The switch from weekly to biweekly auctions also implies that the number of outstanding Treasury bill maturities at the end of each year is cut in half from 39 maturities in 1994–1996 to 19 or 20 maturities in 1998–2011 (Panel (b)). Average auction size doubles from about 2.5 billion dollars in 1994 to five billion dollars in 2011 (Panel (c)). Over this time period, Canadian Gross Domestic Product in current prices increases three times, so auction size grows at a slower rate than the economy. The total number of securities dealers that bid in the Treasury bill auctions decreases gradually over time, but the number of primary dealers stays approximately constant (Panel (d)). Treasury bond auctions are held less frequently than Treasury bill auctions. The annual frequency is approximately constant over time with the exception of the recent increase in 2009–2011 (Panel (e)). The number of Treasury bonds that are outstanding at the end of the year decreases over the sample period from about 90 to 40 (Panel (f)). The decrease is the result of a switch in policy that takes place in the mid-1990s from issuing new Treasury bonds to reopening existing securities. Adding the 20 Treasury bill maturities from Panel (b) to the 40 Treasury bond maturities from Panel (f) implies that the Canadian yield curve consists of about 60 data points at the end of the sample period. Average Treasury bond auction size is approximately constant over time (Panel (g)). The number of securities dealers in the Treasury bond market is similar to that in the Treasury bill market (Panel (h)).

The Treasury bill auction cycle is highly regular. There are two cycles that we refer to as the one-year cycle and the six-month cycle, respectively, that are held alternating every second week. The one-year cycle begins with the auctioning of a one-year Treasury bill (on average 364 days to

[10] We estimated this range using weekly turnover data from the Bank of Canada. Gravelle (1999) and Fleming (2003) provide similar estimates from the 1990s.

Figure 2: Canadian Treasury Market



The number of auctions, the number of securities that are outstanding at the end of the year, average auction size in billion Canadian dollars, and the number of securities dealers at the end of the year. From October 1998, the bidders are divided into primary dealers (dark grey portion of each bar) and secondary dealers (light grey portion).

maturity). The same security is reopened two weeks later with two weeks less to maturity (350 days to maturity). The security is reopened a second time three months before maturity (98 days to maturity, on average).[11] The six-month cycle is similar, it begins with a six-month bill that is immediately reopened two weeks later, and then reopened a second time three months before maturity. A complete Treasury bill cycle thus consists of one new auction and two reopening auctions, which means that one third are new auctions and two thirds are reopening auctions.[12] From 1994–1996, there are 26 Treasury bill maturities resulting from the one-year cycles and another 13 maturities from the 26 six-month cycles, together 39 maturities outstanding at the end of each year (Panel (b) of Figure 2). The average size of the first reopening auction equals average new auction size, i.e., the first reopening doubles the outstanding volume, and the average size of the second reopening auction equals twice the average new auction size, so that the outstanding volume doubles once more. The average bid-to-cover ratio is 2.1, and it is approximately equal in new and reopening auctions.

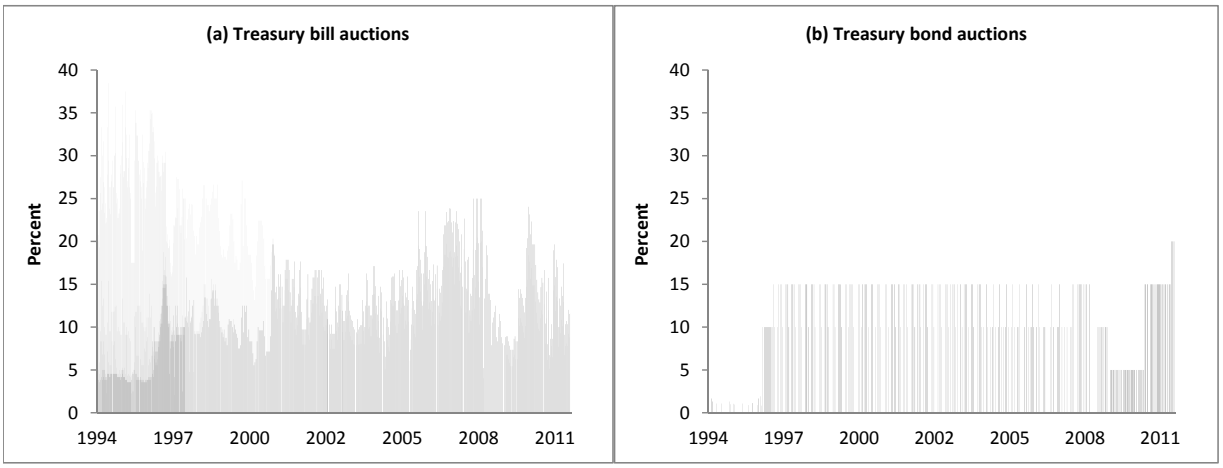
The Treasury bond cycle is also regular. A two-year cycle consists of one new auction followed by one reopening auction next quarter. Two new maturities are opened each year (two cycles). A five- or a ten-year cycle consists of one new auction followed by three quarterly reopening auctions during the first year of the life of the bond (one cycle). The bond is not reopened after the first year. A 30-year cycle begins with a new auction followed by seven semi-annual reopening auctions during the first four years of the life of the bond. The 30-year bond does not reopen as the bond gets closer to maturity. There is one new 30-year cycle every four years. Reopening frequencies increase from 2009–2011 (see Figure 2, Panel (e)), when two-year bonds are issued twelve times per year (four cycles of one new auction followed by two monthly reopening auctions), three-year bonds are added (four cycles of one new auction followed by two monthly reopening auctions), and

[11] Since 1979, the United States also reopens its Treasury bills. A regular Treasury bill cycle begins with an auction of a one-year Treasury bill that is subsequently reopened with six months to maturity and again with three months to maturity. A six-month cycle begins with a six-month Treasury bill followed by a reopening of a three-month Treasury bill. Before 2001, Treasury notes and bonds are not reopened. Since 2001, the Treasury reopens the ten-year note and the 30-year bond twice in the quarter following the new auction.

[12] From 1998–2011, three Treasury bill auctions are held simultaneously every second week, thus resulting in $3 \times 26 = 78$ auctions per year. Before 1998, there are three Treasury bill auctions every week alternating between the one-year cycle and the six-month cycle. At this time, the one-year cycle is made up of one new security and three subsequent reopenings, and the six-month cycle of one new security and one reopening. This auction schedule implies $3 \times 52 = 156$ auctions per year of which one third are new auctions and two thirds reopening auctions.

five-year bonds are auctioned six times per year (two cycles of one new auction followed by two bimonthly reopening auctions). There are minor deviations from these rules. One Treasury bond is auctioned on each auction day, and each new Treasury bond has a unique maturity date.

Figure 3: The Bank of Canada Portion



The figure shows the percent of the auction awards that is reserved for the Bank of Canada. The portion varies with security and over time.

The securities dealers' share of the auction awards is approximately 77%. The remaining awards are approximately divided between the Bank of Canada 13% and customers 10% that submit bids in the auctions through the securities dealers. The market share of the securities dealers is comparable to that in the United States, where securities dealers obtain 70% of the awards with the remainder split between customers 25% and non-competitive bids 5% (Fleming (2007)). Non-competitive bids in Canada sum up to less than 1%. The Bank of Canada purchases securities for balance sheet management and, since 2002, for overnight loans to short bidders that struggle to meet physical delivery. The Bank of Canada bids non-competitively up to 40% of the Treasury bill auction awards, but the portion fluctuates widely over time (Panel (a) of Figure 3). In the Treasury bond auctions, the Bank of Canada portion is between 5% and 20% (Panel (b)). In this plot, we also see an initial stretch of small numbers before 1996 that result from competitive bids submitted by the Bank of Canada for 0.2% of the auction awards, on average, and never more than 2%. Average auction size in Figure 2 above and throughout the analysis of this paper includes the Bank of Canada portion.

2.2 Auction and Bidding Limits

The Bank of Canada bidding rules limit the quantity a bidder can demand in an auction. The objective is to prevent a single bidder from cornering the auction. Unlike the Treasuries of Japan, United Kingdom, and United States, which restrict the maximum award to a single bidder, the Bank of Canada restricts bidding itself.[13] The maximum bid quantity, which is denoted the auction limit, is a function of the pre-auction inventory position. For a bidder with negative inventory, the auction limit is a constant referred to as the bidding limit. When the bidder holds a long pre-auction inventory position, the bidding limit is reduced by the bidder's net long position. Using mathematical language, the auction limit can be expressed as:

$$A_i = \max\{B_i \times Q - \max(y_i - B_i \times S, 0), 0\} \tag{1}$$

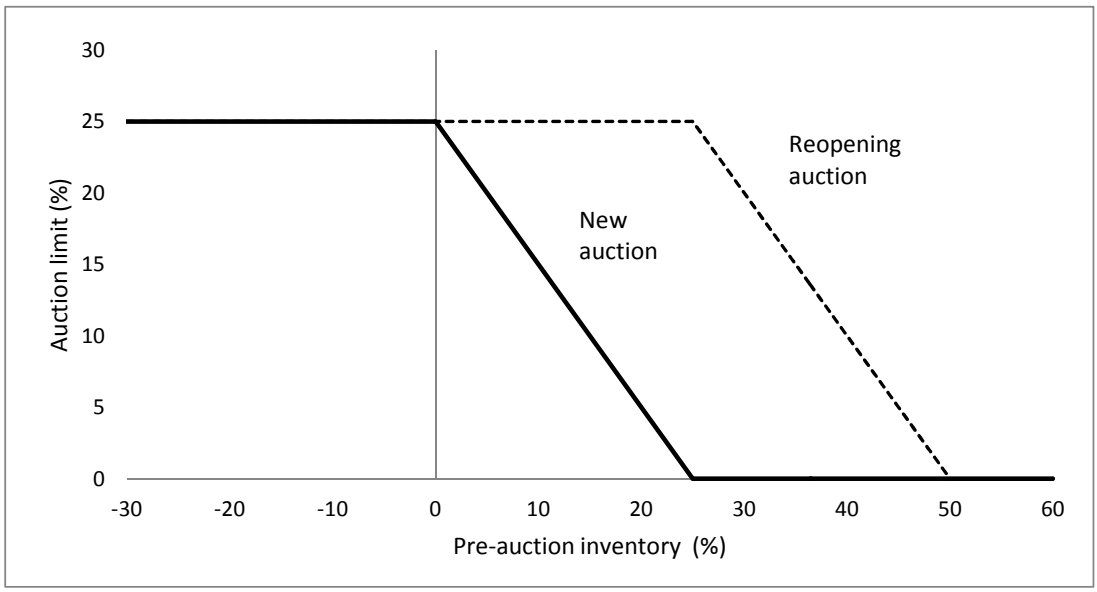
where A_i is bidder i's dollar auction limit (par value), B_i is bidder i's percentage bidding limit, Q is auction size (par value), y_i is bidder i's pre-auction inventory (par value), and S is the outstanding stock of securities before the auction (par value). The bidding limit B_i is a parameter assigned to each bidder by the Bank of Canada. For primary dealers, it equals 25% in Treasury bill auctions and between 10% and 25% in Treasury bond auctions depending on the bidder's performance in the primary and secondary markets (see Bank of Canada (1998)). Secondary dealers are assigned smaller bidding limits.

In Figure 4, we illustrate the auction limit numerically for a bidder with a 25% bidding limit. The solid line is the auction limit in a new auction, and the dashed line is the auction limit in a reopening auction that exactly doubles the outstanding stock of securities. For short and neutral bidders, the maximum bid quantity is 25% in both new and reopening auctions. For long bidders, the maximum bid quantity in a new auction is reduced by the net long position until the auction limit equals zero. In reopening auctions, a bidder with a net long position less or equal to 25%

[13] In the United States, Japan, and United Kingdom, bidders can demand as many securities as they want, but the awards to any bidder is limited to 35%, 30%, and 25%, respectively, of the stock of securities that are outstanding after the auction. In the United States, a single bid (price-quantity pair) cannot exceed 35% of the awards, but a bidder can submit as many bids as he wants. See Garbade and Ingberg (2005) for the history of the 35% rule in the United States. The treasuries of many small countries allow free bidding (see Appendix B of the Joint Report on the Government Securities Market (1992)).

is allowed to bid up to his bidding limit, which means that he is allowed to double his inventory position. When the net long position exceeds 25% of the reopening auction, the maximum bid

Figure 4: Auction Limit

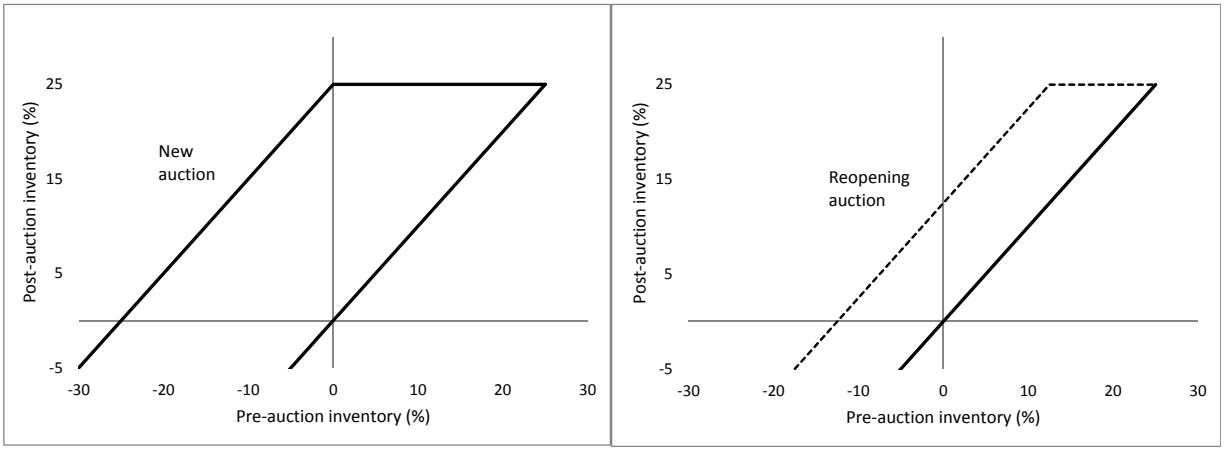


The figure shows the auction limit as a function of the pre-auction inventory of a bidder with a 25% bidding limit in a new auction (solid line) and a reopening auction that exactly doubles the outstanding volume of the security (dashed line). The auction limit and the pre-auction inventory position are expressed in percent of the par value of the current auction (new securities).

quantity is reduced by the excess inventory position until the auction limit is zero. When the auction limit is zero, the bidder is not allowed participate in the auction.

Equation (1) implies that a bidder cannot control more than 25% of the outstanding stock after the auction. In Figure 5, we plot the boundaries of the post-auction inventory of a bidder with a 25% bidding limit. In both figures (new and reopening auctions), we express the pre- and post-auction inventory in percent of the outstanding stock after the auction. Since the maximum auction limit is 25% of the current auction, the feasible set of post-auction inventories in percent of the outstanding stock is necessarily compressed in a reopening auction. Both figures stress the purpose of the auction limit, which is to prevent any bidder from controlling more than 25% of the float after the auction.

Figure 5: Post-Auction Inventory Boundaries



The figure plots the boundaries of the post-auction inventory as a function of the pre-auction inventory of a bidder with a 25% bidding limit. The pre- and post-inventory positions are expressed in percent of the par value of the outstanding stock (old plus new securities).

For monitoring purposes, bidders in the Canadian Treasury auctions must report their pre-auction inventory position to the Bank of Canada at the time of bidding.[14] A pre-auction inventory position, short or long, is built in the when-issued and secondary markets. In addition to the inventory positions from the when-issued and the secondary markets, bidders must report any position in the auctioned security from forward and futures contracts, guarantees, and strips to the extent that such contracts are available.

2.3 Data

We study bidder behavior in the post-regulatory environment from October 1998 through 2011, when bidder's pre-auction inventories are reported to the Bank of Canada. Primary market data are provided by the Bank of Canada. Summary statistics that are released to market participants include the auction date, terms of the tender, auction size, total competitive demand, total non-competitive demand, the quantity withheld by the Bank of Canada, the stop-out yield, and the quantity-weighted average winning yield. With the permission of the Bank of Canada, we also have

[14] Bidders in United States Treasury auctions must also report their pre-auction inventory (see Garbade and Ingberg (2005) for details). The motivation is the same.

the auction bids that are not available to market participants. For each bid in the auction data set, there is an auction identifier, a bidder numerical code that varies randomly over time, a variable that indicates when a bid is submitted by a primary dealer, a secondary dealer, or a customer, a bid yield that we convert into price, quantity demanded, quantity awarded, the bidder's pre-auction inventory, and the bidder's auction and bidding limits.

Treasury securities are traded over the counter. Securities dealers, brokers, and inter-dealer brokers post indicative bid and ask quotes on the Bloomberg screen. Bloomberg retains and stores the midpoint between the bid and the ask at the end of the day, averaged across dealers after deleting outliers. We estimate bid discounts and auction underpricing against the secondary market midpoint, whenever this is available, and the when-issued market midpoint otherwise. There are gaps in the time-series; we identify matching auction-day midpoint quotes for 720 of 1032 Treasury bill auctions (70%) and for 232 of 240 Treasury bond auctions (97%). Finally, we estimate price volatility in the secondary market using bond indexes from the securities that most closely mimic three-, six-, and twelve-month Treasury bills, and two-, three-, five-, ten- and 30-year Treasury bonds. The bond indexes are complete. They are provided by the Bank of Canada.

3 Bidder Behavior with Pre-Auction Inventory

In this section, we analyze how pre-auction ownership influences bidder behavior in the auction. We find that short and long bidders bid higher prices than neutral bidders, and they demand larger quantities. The differences between short and long versus neutral bidders are less pronounced deeper into the auction cycle, and they vary over time. The aggressive bidding by short and long bidders translates into smaller bid discounts and less underpricing in auctions with large negative or positive, aggregate pre-auction inventory.

3.1 Methodology

We estimate a multi-variate regression model of bidder behavior with pre-auction inventory. The regressions take the following general form:

$$b_{ij} = a_0 + a_1\text{SHORT}_{ij} + a_2\text{LONG}_{ij} + a_3\text{SIZE}_j + a_4\text{VOLAT}_j + e_{ij}, \tag{2}$$

where SHORT denotes negative pre-auction inventory, LONG is positive pre-auction inventory, SIZE is auction size, and VOLAT is price volatility estimated with the ARCH(2) model used by Nyborg, Rydqvist, and Sundaresan (2002). We use subindex i for bidder and j for auction. The construction of the dependent variable b_{ij} follows the methodology in Nyborg, Rydqvist, and Sundaresan (2002). First, for each demand schedule submitted in an auction, we compute the quantity-weighted average price:

$$\mu_{ij} = \sum_{k=1}^{n} \left(\frac{q_{ijk}}{q_{ij}} \right) p_{ijk}, \tag{3}$$

where p_{ijk} is the price and q_{ijk}/q_{ij} is the weight associated with bid k. The equal-weighted average across bidders' midpoints is denoted with $\bar{\mu}_j$. We measure the location of each demand schedule relative this auction average:

$$\text{PBID}_{ij} = \mu_{ij} - \bar{\mu}_j. \tag{4}$$

Second, the quantity demanded by a bidder in an auction is the sum of his bids q_{ij} divided by auction size Q_j:

$$\text{QBID}_{ij} = \sum_{i=1}^{n} q_{ij}/Q_j, \tag{5}$$

Finally, the quantity awarded a bidder in an auction is the sum of awarded bids q^*_{ijk} over auction size:[15]

$$\text{QWIN}_{ij} = \sum_{k=1}^{n} q^*_{ijk}/Q_j. \tag{6}$$

The central exogenous variable is the pre-auction inventory position scaled by auction size. For ease of interpreting the regression coefficients, we transform negative pre-auction inventory into a

[15] We do not analyze bid dispersion (number of bids, bid standard deviation, and bid skewness), which is less interesting when the bidders are constrained to maximum seven bids.

positive number, i.e., we multiply by minus one. In the price regression, we interact pre-auction inventory y_{ij} with duration:

$$\begin{aligned} \text{SHORT}_{ij} &= -(y_{ij}/Q_j) \times \text{DURAT}_j, \qquad \text{if } y_{ij} \leq 0, \\ \text{LONG}_{ij} &= (y_{ij}/Q_j) \times \text{DURAT}_j, \qquad \text{if } y_{ij} > 0. \end{aligned} \tag{7}$$

The price regression is estimated with ordinary least squares. Standard corrections for heteroscedasticity and serial correlation make little difference. The quantity regressions are estimated with tobit analysis because the dependent variable is capped by the auction limit. The auction limit is persistent over time, but it varies across bidders, and it is a function of pre-auction inventory. To allow tobit estimation with standard software packages, we include only those bids that are subject to a 25% auction limit. This means that we delete the bids of primary dealers with less than 25% bidding limit, all secondary dealer bids, and all customer bids. It also means that we delete all bids to the right of the kink in the auction limit function (see Figure 4). Approximately one fifth of the data are lost by this requirement. The final sample comprises of a homogenous set of approximately equally large banks. For consistency, we estimate both the price and the quantity regressions within the reduced subset. We estimate one regression at a time as opposed to estimating a simultaneous equation system.

3.2 Regression Results

The regression results are reported in Table 1. Bidding behavior varies with pre-auction inventory. Bidders with negative pre-auction inventory bid higher prices and demand larger quantities and, as a result, obtain a larger share of the auction awards than neutral bidders. Bidders with positive pre-auction inventory also bid aggressively, although the regression coefficients are smaller on the long side. The combined behavior of short and long bidders implies a tilted V-shaped bid function. The slope coefficients are economically meaningful. In a one-year Treasury bill auction, a bidder that enters with a –25% inventory position bids 2.7 price basis points higher than a neutral bidder for an expected 24% of the awards.[16] The bid premium is of the same order of magnitude as

[16] These point estimates are obtained by multiplying the regression slope coefficients from Table 1 by 0.25.

Table 1: Bidder Behavior with Pre-Auction Inventory

Dependent variable	Intercept	SHORT	LONG	SIZE	VOLAT	R^2	#Obs.
			A. Treasury bill auctions				
Price	–0.002 (–16.5)***	0.108 (33.3)***	0.043 (10.7)***	n/a	n/a	0.110	9,278
Demand	0.200 (64.2)***	0.808 (35.0)***	0.562 (21.3)***	–0.003 (–5.6)***	–0.371 (–9.3)**	n.a.	9,278
Awards	0.053 (19.3)***	0.941 (51.8)***	0.353 (16.6)***	0.001 (1.5)	–0.124 (–3.5)***	n.a.	9,278
			B. Treasury bond auctions				
Price	0.015 (3.2)***	0.065 (10.0)***	0.052 (6.0)***	n/a	n/a	0.068	1,706
Demand	0.339 (23.0)***	0.337 (6.7)***	0.048 (1.4)	–0.026 (–6.1)***	–0.019 (–5.0)***	n.a.	1,706
Awards	0.066 (5.6)***	0.227 (8.4)***	0.138 (5.0)***	0.003 (0.8)	–0.001 (–0.3)	n.a.	1,706

The table reports the results of regressing measures of bidder behavior on short and long pre-auction inventory, auction size, and price volatility. The price regression is estimated with ordinary least squares. The quantity regressions are estimated with tobit analysis. SHORT has been multiplied by minus one and, in the price regression, pre-auction inventory has been interacted with duration. Price and volatility are expressed in percent of par, while pre-auction inventory, quantity demanded, and quantity awarded are expressed as fractions of auction size, which we measure in billion Canadian dollars. The symbols *, **, and *** denote statistical significance of 10%, 5%, and 1%, respectively.

the secondary market bid-ask spread, the auction intra-bidder spread (the difference between the highest and the lowest bid price within each demand schedule), and the auction average bid discount (the difference between the secondary market price and the auction average bid price).[17] The slope coefficients in Treasury bill auctions (Panel A) generally exceed those for Treasury bonds (Panel B). Quantity demanded decreases with auction size and volatility.[18] Quantity awarded, which is the bidder's share of the auction awards, does not vary with auction size because market shares must add to 100%.

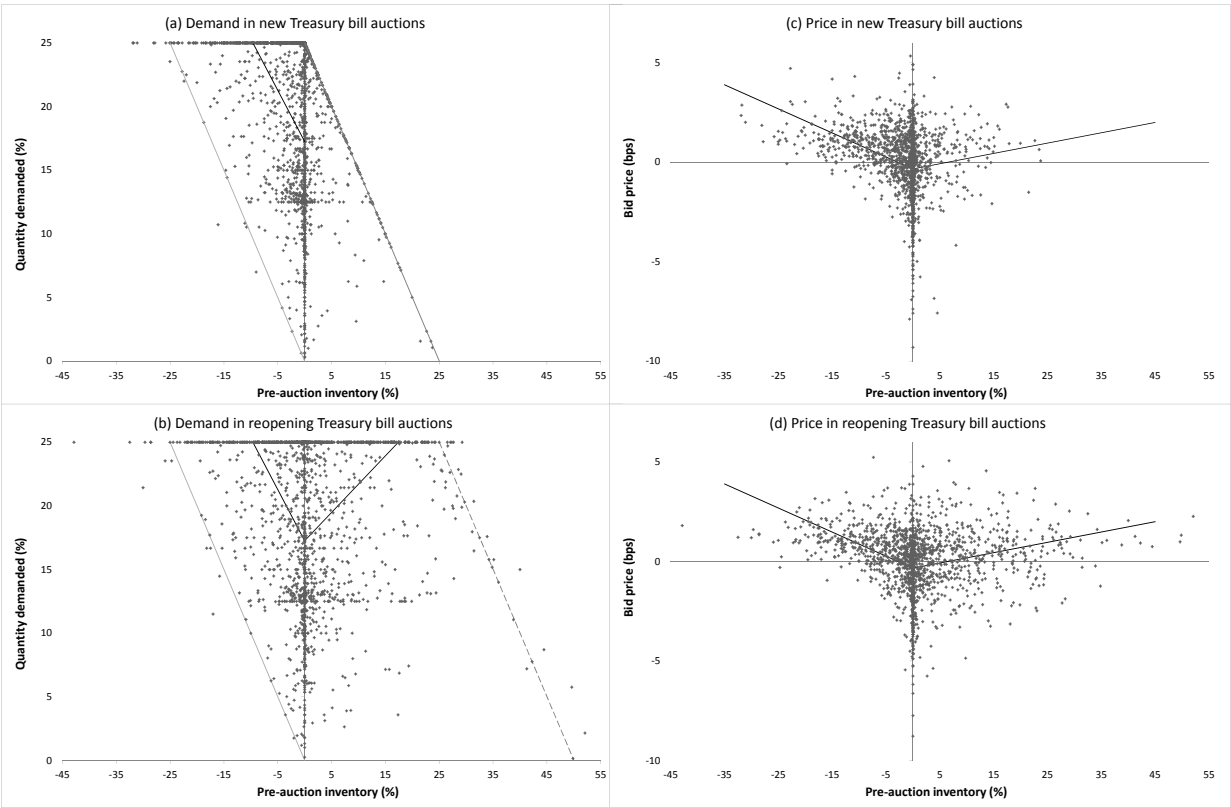
In Figure 6, we plot price bid and quantity demanded in one-year Treasury bill auctions against pre-auction inventory with the estimated regression lines imposed on the four scatter diagrams. Quantity demanded (Panels (a) and (b)) is confined by a parallelogram defined by the auction limit (upper boundary) and the minimum quantity a short bidder must have to cover (lower boundary). Two thirds of the observations fall inside the parallelogram, 30% cluster at the upper boundary, 2% are found at the lower boundary, and 1% (11 observations) fall outside the parallelogram.[19] There is also a visible cluster inside the parallelogram at exactly 12.5%. The striking observation is that the distribution of quantity demanded looks like a T rather than a V. Neutral bidders spread quantity demanded uniformly from virtually zero to the maximum permitted, and both short and long bidders tend to demand the maximum allowed. The scatter of bid prices (Panels (c) and (d)) against pre-auction inventory is better described by a V-shaped bid function, but there is a cluster of low bid prices submitted by bidders with zero pre-auction inventory. We conclude from the visual inspection of the four regression plots that important background variables are omitted from the regression model. Arguably, bidders have different information (strong or weak buy signals). Perhaps, some neutral bidders do not want the auction awards and bid in the auction only to demonstrate active participation according to the primary dealer contract.

[17] D'Souza, Gaa, and Yang (2003) estimate bid-ask spreads between 2.1 basis points (two-year Treasury bonds) and 10.9 basis points (30-year Treasury bonds). For one-year Treasury bills, the average intra-bidder spread is 2.4 basis points, and the auction average bid discount is 2.0 basis points (Table 4).

[18] Auction size and volatility are not relevant for bid price relative the average bid price in the auction because all bids move proportionally with changes in auction size and volatility.

[19] Most short bidders demand more than they need to cover, probably as a response to competition (the aggregate bid-to-cover ratio exceeds two). The few observations that fall outside the parallelogram could be mistakes or data errors. Eight of those observations are short bidders with a pre-auction inventory below –25%. These bidders know in advance that they will be short after the auction.

Figure 6: Bidder Behavior in Treasury Bill Auctions



The four figures plot quantity demanded and price bid against pre-auction inventory in percent of auction size. The quantity plots (Panel (a) and (b)) display the auction limit (upper boundary of the parallelogram) and the minimum quantity that is required to cover a short inventory position in the auction (lower boundary of the parallelogram). All four plots also display the regression lines estimated in Table 1.

Table 2: Bidder Behavior over the Auction Cycle

		Reopening order					
		New	1	2	3	4	≥ 5
		A. Treasury bill auctions					
Price	SHORT	0.108 (25.5)***	0.105 (22.6)***	0.180 (13.3)***	—	—	—
	LONG	—	0.044 (10.8)***	0.077 (3.5)***	—	—	—
Quantity	SHORT	0.912 (24.3)***	0.804 (20.9)***	0.723 (20.1)***	—	—	—
	LONG	—	0.553 (18.8)***	0.596 (11.0)***	—	—	—
		B. Treasury bond auctions					
Price	SHORT	0.161 (3.1)**	0.126 (5.6)***	0.047 (4.4)***	0.049 (4.0)***	0.069 (3.3)***	0.091 (7.5)***
	LONG	—	0.135 (5.5)***	0.049 (3.2)***	0.041 (2.4)**	0.047 (2.1)**	0.042 (2.5)**
Quantity	SHORT	1.492 (5.5)***	0.814 (5.9)***	0.407 (4.3)***	0.205 (3.1)***	0.223 (1.5)	0.180 (1.8)*
	LONG	—	0.127 (1.7)*	0.012 (0.2)	0.058 (1.0)	0.223 (1.8)*	0.396 (1.6)

The table reports the results of regressing price bid and quantity demanded on short and long pre-auction inventory interacted with a dummy variable for each stage of the auction cycle, auction size, and price volatility. The intercept and the slope coefficients of auction size and volatility are omitted from the table. The details of the regression analysis are explained in Table 1. The symbols *, **, and *** denote statistical significance of 10%, 5%, and 1%, respectively. The estimation is based on 9,278 bids submitted in Treasury bill auctions and 1,706 bids in Treasury bond auctions.

The effect of pre-auction inventory on bidder behavior decreases over the auction cycle. To quantify the effect of the reopening order, we interact pre-auction inventory with an indicator variable for each stage of the auction cycle. The set of slope coefficients of short and long bidders are reported in Table 2, where we have omitted the regression intercepts and the coefficients of the control variables for brevity. The decreasing pattern of regression coefficients is best seen in the Treasury bond auctions that are reopened many times (Panel B). In the price regressions, the slope coefficients of short bidders decrease from 0.16 to about 0.08. In the quantity regressions, the slope coefficients of short bidders decrease from 1.5 to 0.2 in the late reopening auctions. The decreasing regression coefficients suggest that short bidders are increasingly less concerned with falling short when the outstanding stock of Treasury bonds grows. The dampening effect of the reopening order may explain why the regression coefficients are smaller in the Treasury bond subsample (Table 1 above). In fact, the slope coefficients in the new auctions and the first reopening auctions are about the same for Treasury bills and bonds.

The effects of pre-auction inventory on price bid is cyclical. The regression slope coefficients peak in 2008 during the global financial crisis, which suggests that bidder behavior varies with uncertainty. To capture the time-series effects, we interact pre-auction inventory with an indicator variables that divides up time into seven two-year periods. The regression coefficients of short and long bidders are reported in Table 3 with the regression intercepts and the coefficients of the control variables omitted. The time-series effects are the strongest in the Treasury bill auctions, where the slope coefficient of short bidders increases from about 0.08 in the mid-2000s to 0.24 during the global financial crisis in 2008–2009 (Panel A). The regression coefficients of quantity demanded are not cyclical. They fluctuate around one on the short side and around one half on the long side.

3.3 Cost of Capital

The behavior of short and long bidders suggests that auctions with large negative or large positive, aggregate pre-auction inventory exhibit smaller bid discounts and less underpricing. The auction-average bid discount is the difference between the secondary market price and the equal-weighted average of bidders' quantity-weighted average bid prices μ_{ij}. Underpricing is the secondary market

Table 3: Bidder Behavior over Time

		1998-99	2000–01	2002–03	2004–05	2006–07	2008–09	2010–11
		A. Treasury bill auctions						
Price	SHORT	0.115	0.101	0.080	0.080	0.132	0.246	0.175
		(15.2)***	(18.1)***	(12.5)***	(9.9)***	(16.2)***	(16.7)***	(13.2)***
	LONG	0.051	0.017	0.022	0.029	0.045	0.076	0.045
		(3.4)***	(1.4)	(1.9)*	(3.2)***	(4.9)***	(9.2)***	(4.9)***
Quantity	SHORT	0.464	1.030	1.405	1.401	1.427	1.636	1.700
		(6.8)***	(16.6)***	(16.6)***	(15.7)***	(15.7)***	(10.1)***	(11.8)***
	LONG	0.087	0.549	0.564	0.906	1.056	0.628	0.743
		(0.7)	(5.2)***	(5.7)***	(9.3)***	(10.2)***	(7.9)***	(7.9)***
		B. Treasury bond auctions						
Price	SHORT	0.196	0.067	0.056	0.034	0.060	0.099	0.083
		(6.0)***	(2.8)***	(5.8)***	(1.8)*	(4.2)***	(5.0)***	(4.8)***
	LONG	0.117	–0.062	0.037	0.015	0.045	0.072	0.115
		(1.6)	(–1.1)	(0.6)	(0.8)	(2.6)***	(5.7)***	(3.9)***
Quantity	SHORT	0.089	0.106	0.074	0.071	0.032	0.022	–0.001
		(3.8)***	(4.1)***	(3.8)***	(3.3)***	(3.1)***	(1.8)*	(–0.1)
	LONG	0.133	0.009	0.211	0.027	0.034	0.000	–0.032
		(2.0)**	(0.3)	(2.4)**	(1.7)*	(2.0)*	(0.0)	(–2.2)**

The table reports the results of regressing price bid and quantity demanded on short and long pre-auction inventory interacted with a dummy variable for each two-year period, auction size, and price volatility. The intercept and the slope coefficients of auction size and volatility are omitted from the table. The details of the regression analysis are explained in Table 1. The symbols *, **, and *** denote statistical significance of 10%, 5%, and 1%, respectively. The estimation is based on 9,278 bids submitted in Treasury bill auctions and 1,706 bids in Treasury bond auctions.

price minus the weighted-average winning price. Table 4 reports average bid discounts and under-

Table 4: Bid Discounts and Underpricing

	Treasury bills			Treasury bonds				
	3M	6M	12M	2Y	3Y	5Y	10Y	30Y
Bid discount	–0.008	0.008	0.020	0.070	0.085	0.147	0.247	0.899
	(–2.3)***	(6.7)***	(8.7)***	(10.0)***	(4.1)***	(7.6)***	(7.7)***	(11.2)***
Underpricing	–0.012	–0.000	0.002	0.028	0.009	0.030	0.043	0.355
	(–3.6)***	(–0.3)	(1.0)	(4.2)***	(0.4)	(1.6)	(1.5)	(6.2)***
#Auctions	253	225	242	68	17	63	52	32

The table reports average bid discounts and underpricing conditional on duration band (three-, six-, and twelve-month Treasury bills, two-, three-, five-, ten-and 30-year Treasury bonds). The bid discount is the difference between the midpoint between the bid and the ask quote at the end of the day and the equal-weighted average of bidders' quantity-weighted average bid prices. Underpricing is the midpoint at the end of the day minus the weighted-average winning price in the auction. The symbols *, **, and *** denote statistical significance of 10%, 5%, and 1%, respectively.

pricing for each duration band. Observed bid discounts and underpricing tend to be positive, and they increase with duration. The magnitudes are comparable to the corresponding numbers from other studies.[20]

We use regression analysis to examine how bid discounts and underpricing vary with pre-auction inventory:

$$b_j = a_0 + a_1\text{SUMSHORT}_j + a_2\text{SUMLONG}_j + a_3\text{SIZE}_j + a_4\text{VOLAT}_j + e_j. \tag{8}$$

The independent variables are the aggregate inventory positions of short and long bidders, auction size, and price volatility as defined above. As previously, we interact aggregate pre-auction inventory with duration. The regression results are reported in Table 5. The auction-level regressions are statistically weaker than the bidder-level regressions reported above, but the slope coefficients of pre-

[20]Direct comparison across is difficult because secondary market data vary widely in quality. We compare the auction bids to the midpoint between indicative bid and ask quotes, while Nyborg, Rydqvist, and Sundaresan (2002) measure underpricing against indicative bid quotes, Keloharju, Nyborg, and Rydqvist (2005) look at transaction-adjusted bid quotes, and Goldreich (2007) uses when-issued transaction prices. The statistically significant negative underpricing in the three-month Treasury bill auctions casts doubts on using the midpoint between bid and ask.

Table 5: Bid Discounts and Underpricing with Pre-Auction Inventory

Dependent variable	Intercept	SUMSHORT	SUMLONG	SIZE	VOLAT	R^2	#Obs.
			A. Treasury bill auctions				
Bid discount	–0.0258 (–1.9)*	–0.0239 (–2.6)***	–0.0078 (–1.2)	0.0002 (0.3)	2.6400 (3.8)***	0.062	720
Underpricing	–0.0146 (–1.2)	–0.0189 (–2.1)**	–0.0080 (–1.2)	0.0001 (0.2)	1.0995 (1.8)*	0.015	720
			B. Treasury bond auctions				
Bid discount	0.3123 (1.4)	–0.0500 (–0.7)	–0.0118 (–0.3)	–0.0777 (–1.2)	1.4369 (2.7)***	0.451	232
Underpricing	0.1906 (1.6)	–0.0213 (–0.4)	0.0070 (0.2)	–0.0585 (–1.7)*	0.4349 (1.6)	0.190	232

The table reports the results of regressing bid discounts and underpricing on the aggregate pre-auction inventory of short and long bidders, interacted with duration, auction size, and volatility. The regressions are estimated with ordinary least squares. The standard errors are corrected for heteroscedasticity. The estimation is based on 720 in Treasury bill auctions and 231 Treasury bond auctions, respectively.

auction inventory assume the correct sign. Bid discounts and underpricing are smaller in auctions where aggregate inventory of short or long bidders dominate pre-auction ownership structure.

4 Shortfalls and Squeezes

In this section, we demonstrate that shortfalls are common and that short squeeze situations arise. Our objective is to analyze whether the possibility of a post-auction short squeeze can motivate aggressive bidding by short and long bidders in the auction (Section 3). Consistent with bidding behavior, we find that shortfalls and squeezes are less common in the early stages of the auction cycle (Table 2 above and Table 6 below), and they are less common later in the sample (Table 3 above and Table 7 below), when interest rates are low. Most short squeeze situations are probably resolved through regular trading with customers. We identify one extreme auction that may have resulted in a post-auction short squeeze with secondary market price impact.

4.1 Definitions

We structure the empirical analysis by defining shortfall, short squeeze, and market power within a simple model that builds on the market corner models of Dunn and Spatt (1984), Cooper and Donaldson (1998), and Nyborg and Strebulaev (2004). A shortfall means that a bidder with a negative pre-auction inventory ends up with a negative post-auction inventory. A short squeeze results when bidders with negative post-auction inventory must turn to a single long bidder to cover his short position. Market power is the number of units the short bidders must retrieve from a single long bidder to cover their short positions.

Formally, a bidder n has market power over the short bidders, if his post-auction inventory is long and the long position exceeds the aggregate post-auction inventory of all bidders (including bidder n):

$$0 < y_n \quad \text{and} \quad \sum_{i \in N} y_i < y_n \leq 0.25, \tag{9}$$

where y_i is bidder i's post-auction inventory, and 0.25 is the maximum permissible post-auction inventory of any bidder under the Bank of Canada bidding rules (normalizing the outstanding stock of securities to one). This condition means that short squeezes can only occur when the aggregate post-auction inventory is less than 25% of the post-auction stock of securities. It also means that a short squeeze must occur when there is at least one long bidder and the aggregate post-auction inventory is negative. In this case, all long bidders have market power.

These results are based on the assumption that short bidders must turn to one of the long bidders to cover the short position. We rule out that bidders can borrow or purchase the missing securities from the Bank of Canada, from customers that are awarded in the auction, or from trading with customers in the secondary market. We also assume that multiple long bidders do not collude to exercise market power. Whenever short bidders can negotiate with two or more long bidders, we assume that Bertrand competition drives squeeze profits to zero.

If we subtract y_n from both sides, the condition (9) becomes:

$$0 < y_n \quad \text{and} \quad \sum_{i \in N \setminus n} y_i < 0. \tag{10}$$

Hence, bidder n has market power, if and only if his post-auction inventory is long and the aggregate post-auction inventory of all the other bidders is negative. From this expression follows that the amount of market power of long bidder n equals the smaller of the number of units he owns and the number of units the other bidders must obtain from bidder n to cover a short post-auction inventory:

$$z_n = \min\left(y_n, -\sum_{i \in N \setminus n} y_i\right). \tag{11}$$

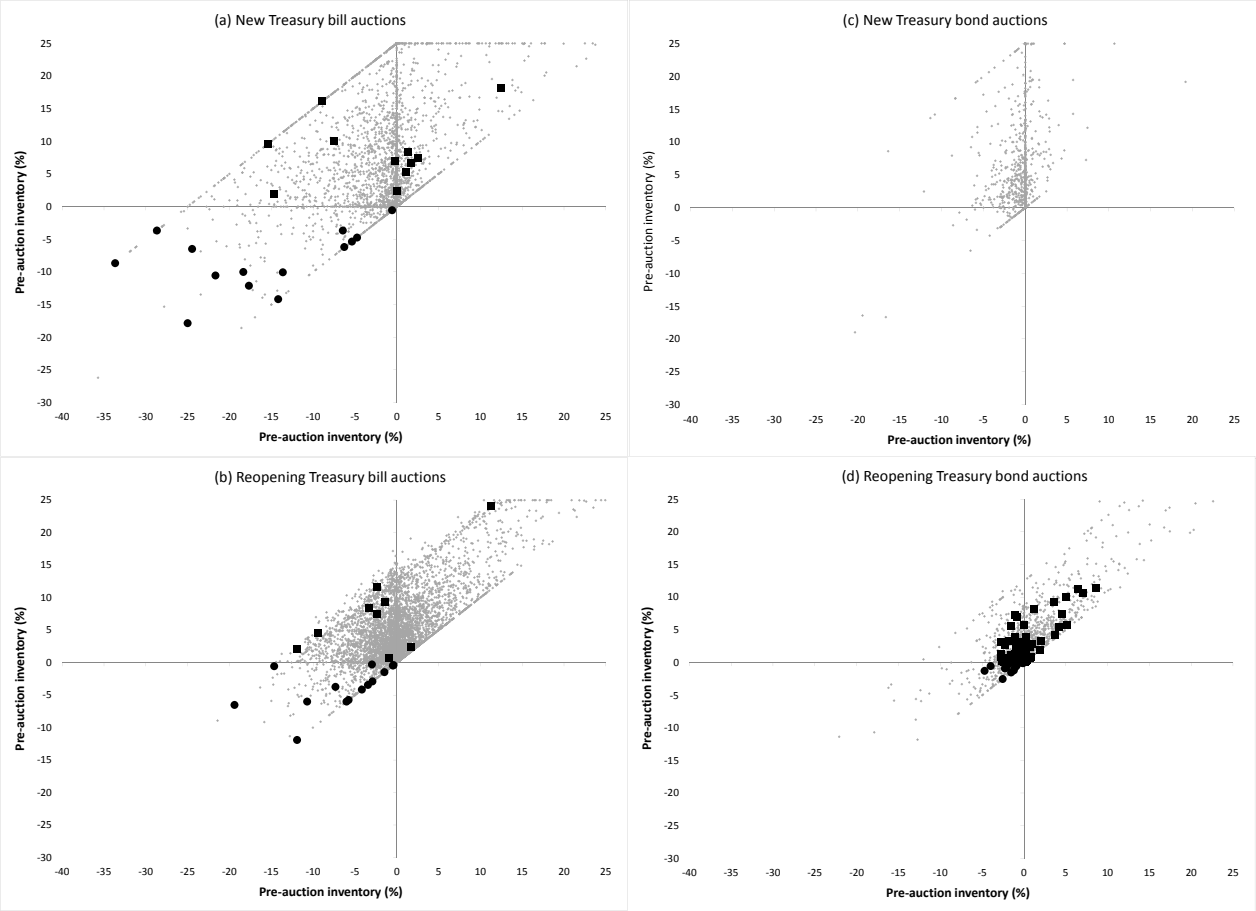
We quantify the severity of a post-auction short squeeze by summing up the market power of the long bidders.

4.2 Evidence

Figure 7 plots each bidder's post-auction inventory against his pre-auction inventory for Treasury bills and bonds, and for new and reopening auctions, respectively. Feasible observations are confined by a parallelogram as in Figure 5 above. Points below the horizontal axis are shortfalls, large filled circles below the horizontal axis are squeezed bidders, and long bidders with post-auction market power are marked with large filled squares above the horizontal axis. A general feature across the four plots is that shortfalls and squeezes are common. In the Treasury bill auction plots, many squeezed bidders are located well below the horizontal axis, which means that the squeeze is potentially severe depending on how many bidders control supply.[21] In reopening Treasury bond auctions, squeezed bidders are located close to the origin, and the resulting squeeze is small. There are no squeezes in new Treasury bond auctions. Another general feature of the four plots is that most squeezing bidders enter the auction with neutral or negative pre-auction inventory. Their market power is the result of aggressive bidding and/or excessive pre-selling by the other securities dealers; it is not the consequence of establishing a large pre-auction inventory position. In fact, more than 50% of ex-post squeezers start out with negative pre-auction inventory, where the maximum squeeze potential is not within reach.

[21] A few bidders that are located at the upper boundary below the horizontal axis enter the auction with a pre-auction inventory, which is so negative that not even the maximum award of 25% is sufficient to cover the short pre-auction inventory position. The existence of these data points is an indication that short bidders are not concerned with short squeeze risk.

Figure 7: Shortfalls and Squeezes



The figure plots each bidder's post-auction inventory against his pre-auction inventory in percent of the post-auction stock (old plus new securities). Bidders with post-auction market power over the short bidders are marked with large filled squares, and bidders that must negotiate with a single long bidder (squeezed) are marked with large filled circles. The total number of observations in the four plots is 14,841.

Table 6: Shortfalls and Squeezes over the Auction Cycle

	Reopening order						
	New	1	2	3	4	≥ 5	All
	A. Treasury bills						
Aggregate pre-auction inventory	–17.6	11.7	–12.4	–	–	–	–6.1
Shortfalls (% of bidders)	10.8	10.3	10.3	–	–	–	10.4
#Short squeezes	5	2	3	–	–	–	10
#Auctions	344	344	344	–	–	–	1,032
Market power (% of auction)	9.4	3.3	4.9	–	–	–	6.8
Market power (% of stock)	9.4	1.6	2.7	–	–	–	5.9
	B. Treasury bonds						
Aggregate pre-auction inventory	–8.6	8.9	3.9	–12.5	–7.1	–21.5	–2.4
Shortfalls (% of bidders)	8.0	13.2	20.1	30.2	25.4	27.9	16.7
#Short squeezes	–	–	6	10	1	3	20
#Auctions	69	67	48	32	10	14	240
Market power (% of auction)	–	–	8.2	6.5	1.7	2.6	6.2
Market power (% of stock)	–	–	2.7	1.6	0.3	0.3	1.7

The table reports the average pre-auction inventory in percent of auction size, percent of securities dealers with negative post-auction inventory (shortfalls), the number of squeezed auctions, and the total number of auctions.

Summary statistics of shortfalls and squeezes over the auction cycle are collected in Table 6. Aggregate pre-auction inventory is negative at all stages of the auction cycle with the exception of the first reopening auction. Average shortfall frequency is 10.4% in Treasury bill auctions (Panel A) and 16.7% in Treasury bond auctions (Panel B). Shortfall frequency is constant across the Treasury bill cycle, while shortfalls are more common deeper into the Treasury bond cycle. The distribution of short squeezes is similar. They are evenly spread out across the Treasury bill cycle, while short squeezes do not arise until the second reopening auction of Treasury bonds. The bottom two rows of each panel reports the number of units of market power conditional on a short squeeze as defined by Equation (11) above. In the ten short squeezes that occur after Treasury bill auctions, the monopolistic securities dealer controls about 6% of both the auction and the outstanding stock after the auction. Average market power in Treasury bond auctions is also 6% of the auction, but since Treasury bonds are reopened more, average market power is only 1.7% of the outstanding stock.

The definition of short squeeze in Equations (9) and (10) assumes that securities dealers with short post-auction inventory must negotiate with a single long dealer that can exercise market power. In practice, a securities dealer may cover a short post-auction inventory position and avoid being squeezed through regular trading with customers. To shed light on this hypothesis, suppose that daily turnover is 8% (annual turnover 2000%), the customer share of total order flow is 10% (the customer share of the auction awards), and customer order flow is unrelated to the auction. Then, the daily trading volume between primary dealers and customers would be 0.8% of the outstanding stock. This estimate is of the same order of magnitude as the average market power in percent of the stock. It means that the opportunity to profit from market power over 1.7% of the stock vanishes in two days. Hence, the short squeezes displayed in Figure 7 and Table 6 are better characterized as short squeeze situations than short squeezes with price impact.

Pre-auction inventory, shortfalls, and squeezes vary over time (Table 7). In the Treasury bill auctions (Panel A), average pre-auction inventory turns from negative to positive, shortfall frequency is cut by two thirds (from 15.8% to 5.6%), and the last short squeeze occurs in 2005. In the Treasury bond auctions (Panel B), average pre-auction inventory also turns from negative to pos-

Table 7: Shortfalls and Squeezes over Time

	1998–99	2000–01	2002–03	2004–05	2006–07	2008–09	2010–11
	A. Treasury bills						
Aggr. pre-auction inventory	–17.4	–19.8	–9.1	–6.3	–1.5	4.5	2.3
Shortfalls (% of bidders)	15.8	11.7	13.4	14.1	9.7	5.1	5.6
#Short squeezes	3	5	–	2	–	–	–
#Auctions	93	156	156	156	156	156	156
	B. Treasury bonds						
Aggr. pre-auction inventory	–17.2	–8.7	–35.6	–8.3	–9.6	20.8	6.8
Shortfalls (% of bidders)	23.4	14.8	22.4	21.0	21.6	12.4	12.8
#Short squeezes	2	1	8	3	3	1	2
#Auctions	19	29	28	28	24	50	62

The table reports the average pre-auction inventory in percent of auction size, percent of securities dealers with negative post-auction inventory (shortfalls), the number of squeezed auctions, and the total number of auctions.

itive, and shortfall frequency decreases, but the number of short squeezes remains approximately constant over time.

A bidder with negative pre-auction inventory can bid aggressively to cover the short position with the auction awards, deliver the securities, receive payment, and invest the proceeds at the general collateral rate. Alternatively, the bidder with short pre-auction inventory can bid cautiously and borrow the securities at the special repo rate to cover the short pre-auction inventory. One would expect that bidding in the auction responds to the difference between the general collateral rate and the special repo rate, referred to as specialness. The degree of specialness depends on the level of the interest rate. Maximum specialness equals the general collateral rate, when the special repo rate is zero and the bidder with negative post-auction inventory is indifferent between borrowing the security and fail to deliver.[22] The general collateral rate is also maximum squeeze profit. Therefore, when the interest rate approaches zero, the maximum cost of being caught short after the auction and the maximum profit from a short squeeze also approach zero. These

[22]Effective May 2009, the US Treasury has adopted a penalty for fail to deliver equal to the greater of 3% minus the fed funds rate or 0%. There is no explicit penalty on fail to deliver in Canada.

arguments imply that concerns with short squeezes depend on the level of interest rate.

Figure 8: The Bank of Canada Target Interest Rate

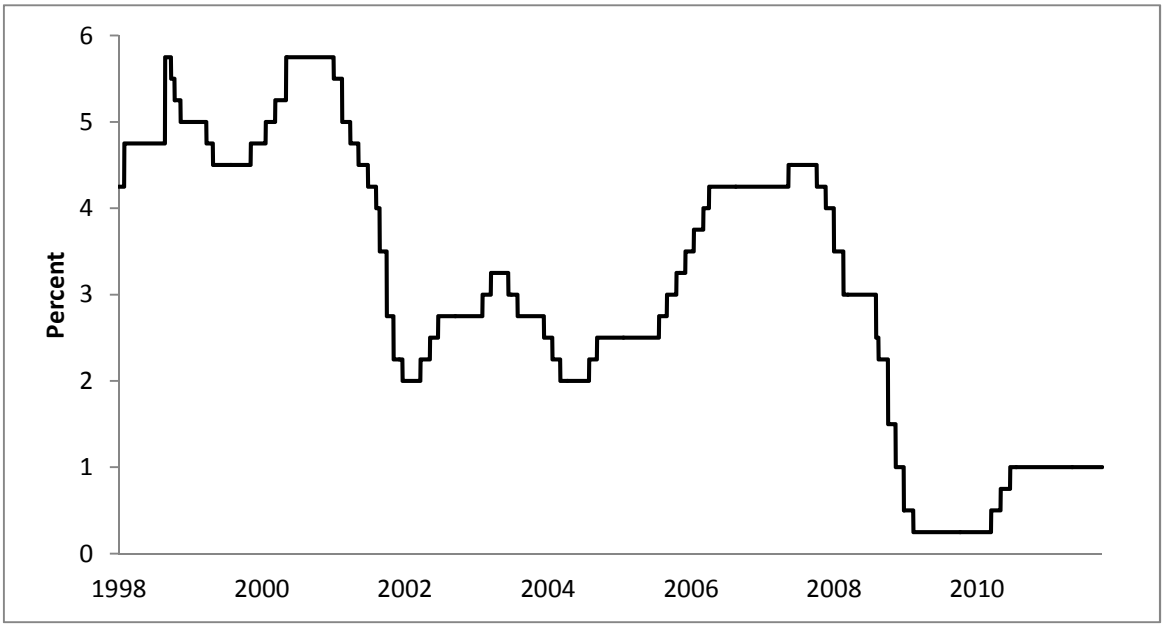


Figure 8 plots the Bank of Canada target interest rate from 1998–2011. The target interest rate decreases from a high of 5.75% in 2000 to a low of 0.25% in 2009. Bidding is particularly aggressive and shortfall frequency unusually low in 2008–2011, when interest rates approach zero. This is the opposite of what the short squeeze hypothesis predicts. In 2008–2011, bidders with negative pre-auction inventory are more concerned than ever to avoid shortfall despite the relatively low cost of borrowing securities and fail to deliver.

4.3 Extreme Pre-Selling

There is one observation in our data set that may have resulted in a short squeeze with secondary market price impact. In this auction, the securities dealers collectively pre-sell 89.5%, which exceeds their market share of approximately 77%. Since the amount of pre-selling exceeds the auction market share, the securities dealers end up together with a negative post-auction inventory of -6.6%. The collective market power of the long bidders is 38.7% of supply. The market power of the long dealers emerges from the large amount of pre-selling in the when-issued market and not

from aggressive bidding. The details of this auction are outlined in Table 8.

Table 8: Treasury Bill Auction with Extreme Pre-Selling

Bidder	Pre-auction inventory	Auction			Post-auction inventory	Market power
		Auction limit	Demand	Price (bps)		
1, 2, 4, 5, 7	–68.4	110.0	96.1	0.4	–45.3	0.0
3, 6	–23.5	50.0	41.7	0.9	18.0	18.0
8–12	0.0	95.0	43.9	–1.0	7.1	7.1
13, 14	2.5	32.5	22.3	0.7	13.6	13.6
Sum	–89.4	287.5	204.0	0.0	–6.6	38.7

Bidder inventories and bidding strategies in a new auction of a one-year Treasury bill held on July 20, 1999. Bidders have been sorted from the one with the most negative pre-auction inventory (bidder 1) to the one with the most positive (bidder 14). Quantities are expressed in percent of the auction awards, and price is expressed in basis points relative the auction average price. Outside the table, the Bank of Canada purchases 9.7% of supply, and customer bids are awarded 7.1% of the auction.

Ten primary dealers and four secondary dealers submit bids in the auction. We sort the bidders by their pre-auction inventory from the most negative (bidder 1) to the most positive (bidder 14). Seven bidders are short, five bidders are neutral, and two bidders enter the auction with long inventory positions. Bidders 1, 2, 4, 5, and 7 fall short after the auction, whereas bidders 3 and 6 cover their short positions in the auction.[23] The post-auction inventory of the five short bidders is –45.3%, and the post-auction inventory of the long bidders 38.7%. The Bank of Canada purchases 9.7%, and customer bids are awarded 7.1% of the auction. The unusual feature of this auction is that even after clearing the short post-auction positions with the other securities dealers, the short bidders must rely on customers to cover the remaining –6.6%. We don't know how this squeeze was resolved, or whether it had secondary market price impact.

[23]Short bidders 1, 2, 4, 5, and 7 demand less than their auction limit, and they do not bid high enough to cover their short positions. Neutral bidders 8–12 submit lower than average bids, while short bidders 3 and 6 and long bidders 13 and 14 submit above average bids. The bids are collected within a narrow band of plus/minus one basis point.

5 Conclusions

We conclude that Treasury securities prices depend on ownership structure. Bidders with large negative or positive pre-auction inventory bid more aggressively than do bidders with neutral pre-auction inventory. Presumably, short bidders want to cover their short pre-auction inventory position, and long bidders, on average, want to increase their inventory positions more than neutral bidders. The dependency of securities prices on ownership structure must reflect a secondary market imperfection. We have investigated and rejected the possibility that post-auction short squeeze motivates the aggressive bidding that we observe in the Canadian Treasury auctions. Standard theories of market microstructure that are based on the costs of holding inventory or adverse selection predict that trading costs increase with uncertainty. Either one may explain the time-series pattern of bidding in the Canadian Treasury auctions. We leave for future research to work out the details.

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