

Intraday Pricing and Liquidity Effects of U.S. Treasury Auctions*

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Abstract

We examine the intraday effects of U.S. Treasury auctions on the pricing and liquidity of the most recently issued 2-, 5-, and 10-year notes. We find that prices significantly decrease in the hours preceding auction and recover in the hours following auction, a pattern not observed on non-auction days. We find that the extent of the price changes is positively related to measures of price volatility, price dispersion, price impact, and bid-ask spreads and negatively related to a measure of market depth. We further find that liquidity tends to be better on Treasury auction days, except immediately around the release of auction results, but that liquidity costs loom large in any strategy that seeks to exploit the pattern of intraday price changes. Our results corroborate the idea that Treasury supply shocks lead to price pressure effects and that dealers' limited risk-bearing capacity helps explain such effects.

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1. Introduction

The extant literature shows that security supply matters to prices, even in a market as liquid as the U.S. Treasury securities market. Studies such as Simon (1991), Simon (1994a), Duffee (1996), and Fleming (2002) thus show that the price of a given Treasury security is related to its supply. More recently, especially with the introduction of the Federal Reserve's large-scale asset purchases (LSAPs), studies have shown a broader linkage between aggregate Treasury supply and prices. Gagnon, Raskin, Remache, and Sack (2011) thus find that the LSAPs resulted in meaningful and long-lasting reductions in longer term interest rates on a broad range of securities. More generally, Krishnamurthy and Vissing-Jorgensen (2012) show that the government debt-to-GDP ratio is negatively correlated with corporate spreads, which reflect a convenience yield attributable to Treasury securities.

Of most relevance to this paper are studies that show that government security supply shocks, even when fully anticipated, have temporary inventory-related effects on prices. Using weekly data, Fleming and Rosenberg (2007) show that secondary Treasury security prices tend to decline in the weeks of Treasury auctions and increase in the following weeks. Using daily data, Lou, Yan, and Zhang (2013) show that Treasury security prices decrease in the few days before auctions and recover shortly thereafter. Beetsma, Giuliadori, deJong, and Widijanto (2013) uncover a similar pattern using daily data in the Italian public bond market.

The argument behind the v-shaped price pattern around auctions is that investors have imperfect capital mobility and dealers have limited risk-bearing capacity. Dealers tend to buy securities at auction and sell them off over adjacent weeks, but need to be compensated for the risk associated with the auction-driven inventory changes. Consistent with this hypothesis, Lou, Yan, and Zhang (2013) find that the extent of this return behavior is positively and significantly related to implied equity and implied interest rate volatility, and negatively and significantly related to broker-dealer leverage growth.

In this paper, we assess price and liquidity patterns around U.S. Treasury security auctions using intraday data, in contrast to the lower frequency data used in earlier studies. With intraday data, we can focus in on the hours surrounding auctions, and exclude the release times of major economic announcements. Moreover, because the settlement time of

Treasury security trades is independent of the time of day at which trades occur, factors important to daily price changes, such as the evolving capitalized value of repo specialness, are not relevant at the intraday level, simplifying the analysis and clarifying the inferences.

In looking at the intraday data, we in fact find the same pattern as past studies, whereby prices fall heading into an auction and then increase after the auction. A similar pattern is not observed on non-auction days, suggesting that it is the auction itself leading to the price pattern. Moreover, we not only observe this pattern for the 2-, 5-, and 10-year notes, as in Lou, Yan, and Zhang (2013), but for the shorter duration 13- and 26-week bills and for securities trading in the when-issued market as well as those that are on-the-run.¹

We further explore the cross-sectional determinants of this price pressure effect. We utilize some of the same market-wide variables as Lou, Yan, and Zhang (2013), such as the MOVE implied Treasury volatility index and the VIX implied equity volatility index as well as a liquidity spread variable and a measure of the dispersion of yields around a smoothed yield curve, similar to the noise measure examined by Hu, Pan, and Wang (2013). We find all of these variables to be positively related to the price pressure effect for each of the 2-, 5-, and 10-year notes (with the coefficients often statistically significant), consistent with the hypothesis of limited dealer risk-bearing capacity.

In addition to the broad marketwide measures, we utilize our intraday data to generate measures of bid-ask spread, quoted depth, price impact, and realized price volatility for each of our Treasury notes, measured as of the day preceding each auction. We show that price pressure effects tend to be positively related with spread price impact, and realized volatility, and negatively related to depth. This provides further corroboration for the idea that limited risk-bearing capacity helps explain the price pressure effect.

In addition to the striking price pattern we observe around auctions, we also examine the behavior of volatility and liquidity around such events. While numerous studies have documented such behavior round macroeconomic releases (e.g., Fleming and Remolona (1999) and Balduzzi, Elton, and Green (2001)) and FOMC announcements (e.g., Fleming

¹ That is, we assess the price behavior of securities on their auction days, before they have been issued, as well as the behavior of previously auctioned securities, which became on-the-run the day following their auction, on the day of the next auction.

and Piazzesi (2005)) there is limited evidence of such behavior around Treasury auctions.² We find that volatility and bid-ask spreads spike higher, and depth plunges lower, around such announcements (consistent with past announcement studies), but that liquidity is generally better on auction days (in contrast to past announcement studies).

Despite mostly better liquidity on Treasury auction days, liquidity costs are still quite large relative to the v-shaped price patterns. We consider a potential trading strategy to exploit the observed price behavior. Specifically, we assume that an investor first sells at the bid one to four hours in advance of an auction and closes out the position at the ask right before auction and, second, buys at the ask right after auction, and closes out the position at the bid one to four hours later. Average returns to this strategy are only significantly positive for the 10-year note, illustrating the significance of trading costs relative to the observed auction price pattern.

Our key findings are illustrated in Figure 1 for each of the 2-, 5-, and 10-year notes. The black lines illustrate the evolution of the average yield relative to the yield at the auction closing time, showing that yields tend to rise in the hours before auction and fell in the hours after auction.³ The gray shaded area illustrates the evolution of the average depth at the inside tier, showing that depth declines sharply at the time of auction, but quickly recovers thereafter. Lastly, the red diamonds illustrate average underpricing, calculated as the yield at auction minus the yield of the auctioned security in the secondary market at the auction close. Underpricing has been examined in numerous prior studies and is not our focus, but provides a nice contrast to the price pressure effects we document. Over our sample, the observed degree of underpricing is of similar magnitude to the intraday price pressure effects for the 10-year note, but less for the 5- and especially 2-year notes.

Our paper proceeds as follows. In Section 2, we provide background on the Treasury market and the associated literature on auction effects. In Section 3, we discuss our auctions

² Some studies have reported selected liquidity/trading activity measures for limited time intervals around Treasury auctions (see, for example, Nyborg and Sundaresan (1996) and Goldreich (2007)). Fleming and Krishnan (2012) document the behavior of volatility and liquidity around auctions of Treasury inflation-protected securities.

³ Recall that yields move inversely to prices, so the v-shaped pattern of prices around auctions corresponds to an inverted v-shaped pattern of yields.

and market data. In Section 4, we present our main results concerning intraday price patterns and some of the factors that influence those patterns. In Section 5, we present various additional results on price pressure effects in other securities and on the relationship between price pressure effects and underpricing effects. Section 6 concludes.

2. Background on Treasury Market and Auction Effects

The U.S. Treasury securities market is one of the largest and most liquid financial markets in the world, with marketable debt outstanding of \$12.0 trillion as of April 30, 2014.⁴ Because of their liquidity, Treasuries are commonly used to price and hedge positions in other fixed-income securities and to speculate on the course of interest rates. The securities' creditworthiness and liquidity also make them a key instrument of monetary policy and a key store of value.

A. Primary Market

Marketable Treasury securities are sold in the primary market via auction. Each auction is announced one or more days in advance by means of a Treasury Department press release. The announcement provides details of the offering, including the offering amount and the term and type of security being offered, and describes some of the auction rules and procedures. Competitive bids must be made in terms of yield and must typically be submitted by 1:00 p.m. eastern time on auction day. Noncompetitive bids must typically be submitted by noon on auction day.

All noncompetitive bids from the public up to \$5 million are accepted. The lowest yield (i.e., highest price) competitive bids are then accepted up to the yield required to cover the amount offered (less the amount of noncompetitive bids). The highest yield accepted is often called the stop-out yield. All accepted tenders (competitive and noncompetitive) are awarded at the stop-out yield. There is no maximum acceptable yield, and the Treasury does not add to or reduce the size of the offering according to the strength of the bids.

⁴ From Monthly Statement of the Public debt
<http://www.treasurydirect.gov/govt/reports/pd/mspd/mspd.htm>

Shortly after the 1:00 p.m. auction deadline, the Treasury announces the auction results. Announced results include the stop-out yield, the associated price, and the proportion of securities awarded to those investors who bid exactly the stop-out yield. For notes and bonds, the announcement includes the coupon rate of the new security. The coupon rate is set to be that rate (in increments of 1/8 of one percent) that produces the price closest to, but not above, par when evaluated at the yield awarded to successful bidders.

To minimize uncertainty surrounding auctions, and thereby reduce borrowing costs, the Treasury offers securities on a regular, predictable schedule. Two-year notes, for example, are announced for auction in the second half of each month, auctioned a few days later, and issued on the last day of the month. Treasury also tries to maintain a stable issue size for issues of a given maturity, so that issue sizes for the 2-year note were a constant \$35 billion between October 2010 and July 2013, before inching down \$1 billion a month to \$32 billion in October 2013, where they have remained since.

B. Secondary Market

Secondary trading in Treasury securities occurs in a multiple-dealer over-the-counter market rather than through an organized exchange. Trading takes place around the clock during the week, although the vast majority of trading takes place during New York trading hours, roughly 7:30 a.m. to 5:00 p.m. eastern time (Fleming (1997)). The primary dealers are the principal market makers, buying and selling securities from customers for their own accounts at their quoted bid and ask prices. In the first quarter of 2014, primary dealers reported daily trading activity in the secondary market that averaged \$525 billion per day.⁵

In addition to trading with their customers, the dealers trade among themselves through interdealer brokers. The brokers offer the dealers and certain other financial firms' proprietary electronic screens or trading platforms that post the best bid and offer prices of the participating firms, along with the associated quantities bid or offered (minimums are \$5

⁵ Federal Reserve Bank of New York (www.newyorkfed.org/markets/statrel.html). As the data is collected from the primary dealers but no other entities, trades between primary dealers are counted twice, and trades between non-primary dealers are not counted at all.

million for bills and \$1 million for notes and bonds). The firms execute trades by notifying the brokers (by phone or electronically), who then post the resulting trade price and size. Interdealer brokers thus facilitate information flows in the market while providing anonymity to the trading firms.

C. Price Pressure Effects

As mentioned earlier, some studies have used daily or weekly data to show that government security prices tend to decline in the period leading to an auction and increase in the period after. Lou, Yan, and Zhang (2013) is the most comprehensive of these, assessing price behavior around auctions of the 2-, 5-, and 10-year Treasury notes from January 1980 to June 2008. In yield terms, they find that yields rise 2-3 basis points in the days up to and including the auction day, and decline about 2 basis points over the subsequent days. While the study examines a 20-day window around auction day, most of the rise and fall seems to occur within 3-4 days of the auction. About half of the reported cumulative yield changes are statistically different from zero, more so for the 2-year note and less so for the 10-year note.

While the findings in past studies are compelling, there are several reasons why it is worth revisiting price behavior around auctions using intraday data. One reason concerns repo market specialness. On-the-run Treasury securities tend to trade special in the repo market. Duffie (1996) explains how this repo market specialness offers owners of the securities an additional return, beyond the securities' cash flows. The return should be capitalized into prices and dissipate over time as securities age. Most of the premium should dissipate by the time of the auction since securities fall off-the-run the day following auction and off-the-run securities trade special to a much lesser extent. Repo specialness is thus consistent with price declines before auction, but steady (and not increasing) prices after auction.

A second reason concerns the long downward trend in Treasury yields. Two-year yields peaked at almost 17% in 1981 and ended 2008 at less than 1%. The average decline in yields over this period was thus more than 1 basis point a week. Naturally, this decline cannot explain the increase in yields before auction, but can perhaps explain a share of the increase observed after auction. More importantly, this long-term decline together with an

increase in yields before auction due to dissipating repo specialness could together create an inverted v-shaped pattern of yields around auction.

A final reason concerns month-end dynamics. Some Treasury securities are regularly auctioned near the end of the month.⁶ At the same time, the market efficiency literature identifies various pricing anomalies, some concerning return behavior around the turn of the month. Ariel (1987), for example, shows that equity returns are unusually high over the last day and first half of the month, which Ogden (1990) argues is consistent with the standardization of payments in the U.S. at the turn of each month. Some of the return behavior around auctions could thus conceivably be related to month-end dynamics.

The use of intraday data eliminates or mitigates each of the possible concerns with analyzing supply effects using lower frequency data. First, repo specialness is irrelevant to intraday returns because the settlement of Treasuries is independent of the time of day at which a trade occurs. That is, a security that is shorted at 11 am and bought back at 1 pm does not need to be borrowed over that interval. Settlement of both trades, if they are not netted, would occur the following day up until 3 pm.⁷

Complications associated with month-end dynamics and trending Treasury yields are also mitigated by the use of intraday data. The use of intraday data allows us to focus in on the interval immediately around auction and avoid other times of significant information arrival (such as the 8:30 am release time of major macroeconomic announcements). While some other information may come out during the period around auctions, and while month-end dynamics may affect intraday patterns, it is hard to imagine how such factors would produce a v-shaped pattern of prices centered around auction time.

This is not to say that use of intraday data does not have its drawbacks. One drawback is that intraday data is harder to come by, so our sample period is necessarily shorter than could be conducted with daily data. Moreover, earlier studies suggest that the price pressure effects occur over several days. If that is the case, then our intraday analysis

⁶ In our sample, 97% of the 2-year notes, 74% of the 5-year notes, and 1% of the 10-year notes are auctioned in the last third of a calendar month (between the 21st and the 30th).

⁷ While most Treasury security trades are for next-day settlement, trades of when-issued securities settle on the issuance day.

will be trying to identify just a fraction of the total price pressure effect. That is, our analysis is geared to cleanly identifying whether there is a price pressure effect, but it is not suited to identifying the magnitude of the price pressure effect to the extent it occurs over multiple days.⁸

D. Underpricing

It is important to distinguish the price pressure effect examined in this paper from the underpricing phenomenon. Underpricing refers to the fact that Treasury securities tend to be auctioned off in the primary market at prices less than the contemporaneous secondary market prices and is documented by numerous studies including Cammack (1991), Spindt and Stolz (1992), and Simon (1994b) . Simon (1994c), Nyborg and Sundaresan (1996), and Goldreich (2007) relate underpricing to auction technique, be it single-price or multiple-price.

3. Data

A. Treasury Auctions

Information regarding auctions comes from Treasury Direct (TD)'s website. In particular, the auction date and security information is available through TD's historical archive while the auction time is gleaned from individual auction announcements as the end of competitive tenders.

Figure 2 summarizes auctions for the notes in our sample by maturity and year of auction. For the 5-year and 10-year notes, we also include scheduled re-openings in dark red and dark green respectively. In total, we are identify 253 2-year auctions, 218 5-year auctions and re-openings, and 155 10-year auctions (including re-openings). From this figure, we see that the 2-year note is generally issued every month during our sample, although in years like 2003, a new auction is replaced with a re-opening. The 5-year note is usually issued on a monthly basis, except during the years 1998 to 2003, when it was issued less often and the

⁸ It follows that some of the interesting ancillary analyses done in Lou, Yan, and Zhang (2013), such as their calculation of how much the price pressure effects raises Treasury borrowing costs, is less suited to this paper.

number of re-openings increased. Finally, the 10-year note is usually issued 4 times a year, although earlier in the sample, sometimes new issues were substituted by re-openings.

B. Intraday Market Information

The intraday price and yield quotes are spliced together using a combination of GovPX and BrokerTec. GovPX is a platform which consolidates data from voice-assisted brokers, and BrokerTec is an interdealer electronic trading platform. Combined, our sample consists of mid-yields and mid-prices for 2-, 5-, and 10-year notes between January 1, 1992 and December 31, 2012; in addition, we have mid-yields and mid-prices of 13- and 26-week bills between January 1, 1992 and June 30, 2001. Between, January 1991 and June 30, 2001, our data comes from GovPX, which contains both on-the-run and when-issued pricing for both Treasury bills and notes. Between July 1, 2001 and June 2013, our data comes from BrokerTec. During this period, due to limitations in the data source, we are only able to see on-the-run quotes for Treasury notes.

We study the 2-, 5-, and 10-year notes and 13- and 26-week bills due to the frequency as well as regularity of their auctions. We also use a mix of GovPX and BrokerTec datasets over the spanned time period due to the difference in coverage across the two sources. As a demonstration, Figure 3 shows the daily data availability for 10-year notes in GovPX (blue) and BrokerTec (black), calculated as the percent of minutes between 7:00 am and 5:00 pm in which we observe at least one quote.⁹ The red line denotes where our GovPX sample ends and our BrokerTec sample begins. In general, our cutoff date captures the periods in which both samples have relatively high coverage.

Both quotes from BrokerTec and GovPX are converted from tick-by-tick limit order book data to one minute snapshots of just the first tier. Using the intraday dataset, we are able to identify quotes during the minute of the auction for 236 out of 240 2-year auctions, 189 out of 194 5-year auctions, and 67 out of 69 10-year auctions (127 out of 129 10-year auctions if we include re-openings). Table 1 summarizes the mid-prices and yields on auction day for 2-, 5-, and 10-year on-the-run notes from our intraday quote data derived from GovPX (Jan 1, 1992-June 30, 2001) and BrokerTec (July 1, 2001- Dec 31, 2012). Mid-price

⁹ While not shown here due to space constraints, the 2- and 5- year notes show a similar pattern.

(mid-yield) is calculated as the average of the best bid and ask prices (yields). The unit of observation is a one-minute snapshot of either price (Panel A) or yield (Panel B) for the on-the-run security during a subsequent auction of the same maturity.

In addition to quotes, we also collect several intraday liquidity and volatility measures for the on-the-run Treasury notes: first tier depth, bid-ask spread, and price volatility. Similar to the quotes analysis, in order to get the best coverage, we use GovPX data between January 1, 1992 and June 30, 2001, and we use BrokerTec data between July 1, 2001 and December 31, 2012. For each auction day, we collect five-minute snapshots of these measures between 7:00 am and 5:00 pm. First tier depth is calculated as the average of depth at the best bid and ask prices across trading days and is measured in millions USD. Bid-ask spread is calculated as the difference of the best bid and ask prices across trading days and is measured in 32nds of a price point. Price volatility is calculated as the standard deviation of five-minute changes in mid-price (the average of the best bid and ask quotes) of the current on-the-run security and is measured in 32nds of a price point.

Table 2 summarizes the intraday liquidity and volatility measures for the 2-, 5-, and 10-year notes. The section marked “All Observations” shows summaries for all five-minute snapshots between 7:00 am and 5:00 pm. In the section marked “5-minute Intervals”, we first take the average (for spread and depth) or standard deviation (for volatility) of 5-minute intervals across all auction days. Then, we calculate summary statistics across the 5-minute intervals. From Table 2, it is evident that the 2-year note is the most liquid, with an average depth of 214 million across all observations and a bid-ask spread of 0.33 32nds. On the other hand, the 10-year note is the least liquid with an average depth of only 21 million and bid-ask spread of 0.75 32nds. The 10-year note also has the highest price volatility of 7.92 32nds, whereas the 2-year note has the lowest price volatility of 1.82 32nds.

C. Explanatory Variables

In order to explain supply effect patterns over time, we use a number of financial market measures, which are summarized in Table 3. These broadly fall into two categories. First, following Lou, Yan, and Zhang (2013), we use standard measures of broad market conditions. These include two widely used volatility measures: the Merrill Lynch Option Volatility Estimate (MOVE) and Chicago Board Options Exchange Market Volatility (VIX)

indices from Bloomberg. In addition, we use Moody's Baa-Aaa spread, which is a commonly used measure of financial distress (for example, see Hakkio and Keeton 2008) from the U.S. Economics Database in Haver. Finally, dealers' risk-bearing capacity is proxied using fitted errors from the Gurkaynak, Sack, and Wright (2006) yield curve. Since a large fitting error suggests opportunity to profit from a pricing discrepancy, and these profits are likely not realized by dealers due to balance sheet limitations, yield curve fitting errors are negatively correlated with dealers' capacity.

Unlike prior studies, we also compute and consider liquidity and volatility measures on the secondary market using our GovPX and BrokerTec order books¹⁰. Average bid-ask spread (or the difference between the best bid and ask quote) and first-tier depth (or the average of depths at the best bid and ask price) are calculated daily between the hours of 7:00 am and 6:00 pm using all observed quotes. Price impact is estimated from weekly regressions of five minute price changes on signed (buyer initiated minus seller initiated) number of trades over the same interval. Finally, price volatility is the daily standard deviation of 5-minute mid-price changes across the trading day. In order to capture market conditions going into the auction day, we match the supply effect at each auction to market variables measured the trading day before¹¹.

4. Empirical Results

A. Intraday Yield/Return Behavior

To understand the supply effect of Treasury auctions on intraday pricing patterns, we compare secondary market quotes to each other around the time of auction. First, we look at rate patterns by calculating average yield difference for the on-the-run note in the six-hour window surrounding auction. Yield difference is calculated as the yield t minutes away from auction minus the yield at time of auction, where t is measured in half hour increments ranging from -180—which corresponds to the quote three hours before auction—to 180—

¹⁰ Similar to the quotes analysis, we use data from the GovPX database from January 1, 1992 to June 30, 2001; and we use data from the BrokerTec database from July 1, 2001 to December 31, 2012.

¹¹ Since the price impact coefficient is measured at a lower frequency on a weekly basis, we use the price impact as of the same week as the auction.

which corresponds to the quote three hours after auction. Table 4 summarizes our findings. In addition, the bold black line in Figure 1 illustrates the average yield differences in one-minute increments for an extended eight-hour window around auction.

Examining Table 4 and Figure 1, we find that the yield tends to be higher at time of auction than around auction, and this effect is especially pronounced in the four hours preceding auction. In fact, for the 2- and 5-year notes, the yield change is generally positive and significant only preceding auction. Following auction, they are still positive but no longer significant. On the other hand, the 10-year note shows positive and significant returns both (90 to 180 minutes) before as well as (60 to 180 minutes) after auction. The magnitude of returns increases further away from time of auction and for greater maturities. In sum, across all three maturities, the yield differences are positive and significant at the 10% level or better in the interval of 90 to 180 minutes before auction.

Next, we examine price patterns by calculating returns for the on-the-run security in the eight-hour window around auction. Intraday return at t minutes from auction is calculated as the sum of the cumulative return based on mid-price t minutes before auction and t minutes after auction¹²:

$$return(t) = \left(\frac{midprice(-t) - midprice(0)}{midprice(-t)} \right) + \left(\frac{midprice(t) - midprice(10)}{midprice(10)} \right)$$

Essentially, this measure, which follows the procedures outlined in Lou, Yan, Zhang (2013), combines the price effect on both sides of the auction. Thus, it is a more robust measure of supply effect compared to yield differences. Table 5 summarizes the average cumulative returns in the eight-hour window around auction in 30-minute increments. Figure 4 further depicts the average return in one minute increments around auction, with a 95% confidence band shaded in light blue.

Across the 2-, 5-, and 10-year Treasury notes examined, we find positive average intraday returns in the eight-hour window surrounding auction for auction days (left-side

¹² Since there is high price volatility shortly after auction due to information contained in the auction results, we compare prices after auction to the price 10-minutes after auction, when it relatively stabilized. While this leads to more robust returns, analyses comparing all prices to the price at auction also yield similar results.

graphs). In fact, in the one to four hours around auction, returns are significant across all maturities and for all 30-minute intervals. In contrast, on non-auction days (right-side graphs), returns in the same window around the usual time of auction, or 1:00 pm, are small and never significantly different from 0. Thus, the pricing patterns that we observe are unique to auction days. Similar to the yields analysis, the magnitude of the price pressure grows as the time window moves further from the auction, but this growth stabilizes after the first two hours. Furthermore, as with the yields analysis, we find that the size of returns becomes larger with larger maturity notes. For example, comparing returns 4-hours from auction, the magnitudes range from 1.49 bps for the 2-year note to 12.51 bps for the 10-year note.

Comparing our findings to that of Lou, Yan, and Zhang (2013), the price patterns and their significance are generally consistent. However, while Lou, Yan, and Zhang find a symmetric price pressure around auction, we find that the effect tends to be much stronger prior to auction—especially for the 2- and 5-year notes. The magnitudes found in our eight-hour window are much smaller than those found in the 10-day window. This is not surprising given that both studies find that the supply effect grows with the length of the window around auction.

Since the time period examined in our study is not identical to Lou, Yang, and Zhang, we recreate their daily returns using our sample period¹³. We then compare the most closely sized windows in each analysis: the four-hour returns in the intraday analysis and the one-day returns in the daily analysis. On one hand, the 5-year note has a one-day return (5.25 bps) about twice the size of the four-hour return (2.5 bps). On the other hand, the 10-year note has a much larger four-hour return (12.51 bps) than one-day return (-3.44 bps). The one-day (1.52 bps) and four-hour returns (1.49 bps) for the 2-year note are very similar. Discrepancies may arise from a number of factors, including the effect of contemporaneous events like macroeconomic announcements. In general, however, we find that the intraday cumulative returns from just the four hours around auction are both significant statistically and economically when compared to average daily returns.

¹³ These results are shown in the appendix, under Table A1.

B. Drivers of Supply Effects

In this section, we attempt to explain the observed supply effect using both broad market conditions as well as platform-specific measures on the trading day before auction. Lou, Yan, and Zhang (2013) suggest that pricing patterns in the secondary market around auction days can be explained by dealers' limited risk-bearing capacity. In order to incorporate large amounts of new issuance into their balance sheets, dealers must take short positions in the secondary market driving prices down. From this reasoning, we expect price pressure to be greater when dealers' capacity is weaker and when stability and liquidity is lower. Similar to past literature, we use measures of implied volatility such as VIX and MOVE as explanatory variables. In addition, we incorporate new measures of capacity and financial distress using a yield curve fitting error and a Baa-Aaa corporate yield spread. In addition, utilizing our secondary market trading platform data, we include several liquidity measures and one realized volatility measure.

In Table 7, we regress price pressure effects, measured as cumulative auction returns in a 10-minute window roughly two hours from auction, on a set of average daily market metrics one day before auction: Merrill Lynch Option Volatility Estimate (MOVE) Index, the yield curve fitting error, the Chicago Board Options Exchange Market Volatility (VIX) Index, and the difference between the Aaa and Baa corporate bonds yields.

Overall, we find that market uncertainty is consistently and positively correlated with higher price pressure effects. More specifically, higher volatility as measured by the VIX and MOVE indices; higher liquidity premium as measured by increasing Baa-Aaa spread; and lower capacity as measured by higher yield curve fitting errors tends to lead to higher returns around auction. The yield curve fitting error is positively and significantly correlated with returns across all three maturities; the MOVE and VIX are positively and significantly correlated with returns for the 5- and 10-year notes; the Baa spread is significantly correlated with returns for only the 10-year note. Using the 10-year note as an example, we find that a one unit increase in the MOVE index is correlated with a 0.27 bps increase in returns; a one bp increase in fitting errors is correlated with a 1.41 bps increase in returns; a one unit increase in the VIX index is correlated with a 0.71 bps increase in returns; and a one bp increase in Baa-Aaa spread is correlated with a 0.10 bps increase in returns.

Next, in Table 8, we regress price pressure effects on a common set of average daily liquidity and volatility measures from the secondary trading platform as of the trading day before auction. These measures include: first-tier depth, bid-ask spread, price impact, and price volatility. Depth is measured as the average of the depth at the best bid and ask prices; bid-ask spread is measured as the difference between the best ask and bid prices; the price impact coefficient is calculated by regressing 5-minute prices changes on net number of orders; and price volatility is calculated as the standard deviation across 5-minute price changes.

Similar to the broader market analysis, we find that lower liquidity and higher volatility is strongly correlated with higher price pressure effects. More specifically, returns are generally higher when depth is lower, bid-ask spreads are higher, price impact is higher, and price volatility is higher¹⁴. For the 5-year note, the relationship between price volatility and auction returns is both positive and highly significant. For the 10-year note, the relationship between bid-ask spread and price impact is both positive and significant. To demonstrate the relative magnitude of their impact, a one standard deviation change in depth, spread, price impact, or price volatility for the 10-year note is correlated with a -2.4, 4.9, 6.8, or 0.6 bps increase in auction-day returns respectively.

C. Exploiting Intraday Patterns

Liquidity and price volatility in the secondary market have been shown to respond quickly to public information in the form of scheduled macroeconomic announcements (for example, see Fleming and Remolona 1999; Balduzzi, Elton, and Green 2001). In contrast, there has been limited study on the effects of nominal Treasury auctions. For instance, Nyborg and Sundaresan (1996) look at when-issued Treasury securities between 1992 and 1993, documenting some evidence of low depth on the secondary market right before auction. Goldreich (2007) shows that pricing patterns in the form of underpricing are positively correlated with bid-ask spreads and yield volatility in the secondary market 30 minutes prior to auction. No study to our knowledge has documented intraday liquidity and

¹⁴ The only deviation from this pattern is price volatility for the 2-year note which is negative but insignificant.

volatility patterns for on-the-run Treasury notes in a sizable window around auction. However, it is natural to expect similar and strong patterns since Treasury auctions are large in size, are scheduled well in advance, and occur with a regular frequency. Furthermore, as a simple trading simulation will demonstrate, any implementation of a strategy which exploits pricing patterns on auction day would need to take contemporaneous liquidity and volatility movements into consideration.

In this section, we examine three different measures of intraday liquidity and volatility on 2, 5, and 10-year Treasury note auction days: quoted depth, bid-ask spread, and price volatility. In Figure 5, we compare the intraday price volatility on the secondary market on auction days (black line) and non-auction days (grey line). For each five minute between 7:00 am and 5:00 pm, price volatility is calculated as the standard deviation of all five-minute price changes across in our sample. In general, the level of volatility on auction days is equal to non-auction days and increasing with the maturity of the security. For both auction and non-auction days, we see notable spikes in volatility around 8:30 am and 10:00 am. These correspond to the times of macroeconomic announcements such as the employment report and are consistent with previous studies on the U.S. Treasury bond market (for example, see Fleming and Remolona 1997). In addition, however, we see a spike at 1:00 pm or shortly after for the auction series alone, suggesting a unique effect from auction results. Using a Brown and Forsythe F-test of sample variances, we find that the auction and non-auction volatilities are significantly different at the 1% (denoted by a shaded diamond) level for all three maturities at time of auction as well as for a short time after auction.

Figure 6 compares the intraday average quoted depth, or the average of depth at the best bid and ask prices, on the secondary market for auction days (black line) and non-auction days (grey line). As a baseline, we see that depth on non-auction days opens at a relatively low level, gradually grows to about double the opening depth around noon, and gradually returns to opening levels by the end of the day. Similar to the intraday volatility measures, there are also notable dips around 8:30 am and 10:00 am, which likely correspond to macroeconomic announcements. On auction days, the general level of depth is greater, but the most noticeable event is the drop in depth at time of auction, ranging from a decrease of roughly 25 million USD for the 5- and 10-year notes to 200 million USD for the 2-year note. While the depth climbs again shortly after auction for the 5-and 10-year notes, the 2-year

note stays at a lower level for a few hours. A two-sample t-test shows that the depth on auction days is significantly larger than non-auction days leading to the auction time, when it is significantly lower. After the end of the auction at 1:00 pm, however, the two series are generally equal.

Finally, Figure 7 compares the intraday average bid-ask spread on the secondary market on both auction days (black line) and non-auction days (grey line). Similar to depth, we find that on non-auction days, liquidity grows throughout the day, peaking around noon. The most noticeable jumps occur around the time of the 8:30 am and 10:00 am macroeconomic announcements¹⁵. We also find that liquidity is a little higher (the spread is a little lower) on auction days leading up to auction across all maturities. However, there is also a salient rise in spread starting at time of auction, and it tends to stay elevated until the end of the trading day at 5:00 pm. A two-sample t-test shows that while spreads at time of auction are not significantly higher on auction days, they are significantly higher in the period shortly after auction, roughly between 1:30 pm and 3:00 pm.

As the intraday analyses reveal, liquidity is generally better on Treasury auction days. However, liquidity costs are still quite large around auction and may significantly impact our observed price patterns, which already have small magnitudes. Thus, we next test a simple trading strategy which tries to take advantage of the observed price patterns. First, we sell (or short) the on-the-run security t minutes before auction at the best bid price, and we buy back the security at auction time at the best ask price. Next, we buy the security 10 minutes after auction (see footnote 12) at the best bid price, and then we sell it t minutes after auction at the best ask price. We allow t to vary between 60, 120, 180, and 240 minutes. The day's profit per security can be calculated as the sum of the ask prices minus the sum of the bid prices. If the mid-price is considered fair price, then one must pay half the bid-ask spread every time he buys or sells the security, so that the net profits are effectively equal to midprice returns minus two bid-ask spreads.

Table 6 summarizes the average returns per security using this simple trading strategy in our sample. We find that this strategy loses money for the 2-year note and has minimal

¹⁵ There is also some indication of another jump shortly after 2pm, which corresponds to the time of the FOMC statement, although it is much smaller than the morning jumps.

returns for the 5-year note. The strategy only produces positive and significant returns for the 10-year note, ranging from five (2 hours around auction) to eight cents (2.5 hours around auction) per \$100 face value. In sum, we find that transaction costs make exploitation of the intraday supply effect pattern costly for smaller maturities and underscore the importance of considering market frictions around auction.

5. Additional Tests

A. Yield/Return Behavior of Treasury Bills

One advantage of our intraday data is that we are able to examine bill auctions, which are auctioned every week, without being affected by adjacent Treasury auctions. For example, if we studied a 10-day window around auction instead, our results would be confounded by the effects of the auction on the following week of the same maturity as well as other bill auctions with different maturities. We specifically chose to study the 13-week and 26-week bills due to their regularity as well as frequency of auctions. Since the 13-week and 26-week bill are auctioned at the same day as well as at the same time, their supply effect is synchronized and strengthened by each other. Due to the high frequency of bill auctions, we also have the benefit of a greater number of observations and potentially stronger effects.

Table 9 summarizes intraday yield changes by 30 minute intervals for 13- and 26-week on-the-run bills around auction time on the subsequent auction date. In this table, we see that the effect of the auction is especially strong and significant leading up to the auction and becomes less strong or even reversed following auction. In fact, while yield change is negative and significant at the 95% level 180 minutes before auction and up to 30 minutes after auction for the 13- and 26 week bill, it is not significantly nor consistently negative in the minutes following this interval. Similar to the notes analysis, we find that the effect of auction gets stronger as we move further before auction. The yield change for the 26-week bill in the four hours prior to auction (0.56 bps) is about double that of the 13-week bill (0.26 bps) in the four hours prior to auction.

Figure 8 depicts the results of Table 9 visually in finer, one-minute intervals. In general, we find a strong, negative effect on yields that gets stronger with the increasing span

of the time window. Similar to notes, the rate of decrease in the differences is fairly steep but levels out after roughly one hour from auction. Compared to the yield changes on Treasury notes, however, these yield differences are notably smaller. For example, while the yield difference four hours before auction for the 26-week bill is about 0.3 bps, the yield difference four hours before auction for the 2-year note is about 1.5 bps—nearly six times greater.

Next, Table 10 summarizes cumulative returns from auction by 30 minute intervals for on-the-run bills around auction time on the subsequent auction date. We find that the 13- and 26-week bills both have very significant (at the 1% level) auction day effects in all of the 8 hours around auction. Since the 26- week and 13-week bills are auctioned on the same day and usually at the same time, it is not surprising that the effect is especially strong. The magnitude of the auction effect for 26-week bills (0.1 to 0.3 bps) is again about double that of the 13-week bills (0.05 to 0.2 bps).

Finally, Figure 9 visually illustrates the findings of Table 10 in one-minute intervals and compares the pattern on auction days to the pattern on non-auction days. We see that the auction-day returns are consistently positive and highly significant in the eight-hour window around auction. On non-auction days, however, the returns tend to oscillate around zero and are not significantly different from zero. Thus, we find while the supply effect for bills is very small on auction day—less than half a basis point—it is highly significant, occur frequently, and are unique to the auction days.

B. When-Issued vs. On-the-Run Behavior

In addition to on-the-run quotes, the GovPX platform also allows us to track when-issued quotes—the prices for positions on the security at auction that day. In this section, using our GovPX quote data from January 1, 1992 to June 30, 2001, we repeat the previous yield and returns analysis to see if there is also a supply effect for securities at auction, and whether this effect is significantly different from than that of the on-the-run security. Under the story of dealers' limited risk-bearing capacity, we would expect a similar effect for when-issued prices. However, because dealers may want to close out their expected Treasury purchases using when-issued trading, we would expect an even stronger price pressure on when-issued quotes.

Table 11 shows the average when-issued yield difference for the auctioned 2-, 5-, and 10-year notes in the six-hour window surrounding auction. This table is calculated using the same methods as Table 4 although we are limited to a much smaller sample size, since when-issued quotes are only available on the GovPX platform. Consistent with on-the-run analysis, we find that the yield difference is generally negative and stronger preceding auction. In fact, the only non-negative yield changes are for the 10-year note following auction, suggesting asymmetric pricing patterns. On the other hand, consistent with past results, we find negative and significant yield changes for 180 to 30 minutes preceding auction in the auctioned 2- and 5- year notes. In addition, we find significant changes for the 30 to 60 minutes after auction for the 2-year note and in the 90 minute window only for the 5-year note.

Table 12 summarizes cumulative returns from auction by 30 minute intervals for the auctioned 2-, 5-, and 10-year notes around auction time. For the 2- and 5-year notes, we find positive and significant returns similar in magnitude to the on-the-run analysis in Table 5. One notable difference is the 10-year note, which shows a negative and generally insignificant return in the eight hour surrounding auction. The discrepancy may be due to the fact that this analysis consists of a much smaller sample and, as we can see in Table 11, the diverging post-auction results tend to dominate the more consistent pre-auction results¹⁶.

Since the when-issued analysis can only be conducted using the January 1992 to June 30, 2011 sample on the GovPX platform, we want to compare the when-issued prices to on-the-run prices over the same sample. Figure 10 shows the findings of Table 12 visually and also compares the average cumulative returns for when-issued securities (black line) to the average cumulative returns for the on-the-run security (red line). We see that for the 2-, 5-, and 10-year notes, the when-issued returns all very closely track that of the on-the-run returns. In fact, when we show the 95% confidence bands around cumulative returns using a dotted black line, we find that the when-issued yield changes are never significantly different from that of the on-the-run yield changes. This demonstrates that the supply effect of Treasury note auctions generally affect both the on-the-run and when-issued trading equally.

¹⁶ Note that this 10-year sample includes only the first issue of each security, while the prior analysis also includes re-openings.

Next, we repeat the above analysis for notes using 13- and 26-week Treasury bills. Table 13 shows the average when-issued yield difference for the auctioned 13- and 26-week bills in the eight-hour window surrounding auction. We find consistently negative yield changes both before and after auction, although the effects tend to be stronger and more significant following auction. While yield changes are significantly negative for the 26-week bill for the entire six hour window, yield changes are also significantly negative for the 13-week bills for all windows except 90 and 120 minutes after auction.

Table 14 next shows cumulative returns from auction by 30 minute intervals around auction time for the auctioned 13- and 26-week bills. Not surprisingly given the strong results found in Table 13, we find the returns to be consistently positive and highly significant in the full six hour window around auction. Extending the window to the eight-hour window around auction, we find that 13-week returns are still positive and significant, and the 26-bills returns are positive but not significant.

Finally, we compare the bills' when-issued prices to their on-the-run prices over a consistent sample. Figure 11 shows the findings of Table 14 visually and also compares the average cumulative returns for auctioned securities (black line) to the average cumulative returns for the on-the-run security (red line). Unlike the notes, we find that returns for the auctioned security appear to be greater and quite different from the on-the-run security, especially in the smaller six-hour window around auction. When we also consider the 95% confidence bands, shown in the graphs using a dotted black line, we find that the average returns on the auctioned 13-week bills are sometimes significantly lower than that of the auctioned security. There is also some evidence of significantly larger returns for auctioned securities in the 26-week bill, but generally, the auctioned security's returns are more volatile and not consistently larger. Overall, for the 13- and 26-week U.S. Treasury bills, we find that supply effects are actually larger for the auctioned security than the on-the-run security.

6. Conclusion

We assess price behavior around Treasury auction using intraday data and find that prices tend to decline in advance of auction and increase following auction. While our results are consistent with evidence uncovered using lower frequency data, we argue that

analysis of intraday data avoids some of the possible confounding factors that affect lower-frequency analyses. Finding a price pressure effect with intraday data thus increases confidence in the findings of the lower frequency analyses.

We relate the price pressure effect to various exogenous variables and find support for the hypothesis that investors have imperfect capital mobility and dealers have limited risk-bearing capacity. In particular, we find that implied Treasury volatility index, implied equity volatility index, and a measure of the dispersion of yields around a smoothed yield curve, are all positively related to the price pressure effect for each of the 2-, 5-, and 10-year notes. We further find that security-specific measures of higher bid-ask spread, higher price impact, higher realized price volatility, and lower depth tend to be correlated with a higher price pressure effect.

We further examine the intraday behavior of volatility and liquidity around Treasury auctions. We find that volatility and bid-ask spreads spike higher, and depth plunges lower, around such announcements, but that liquidity is generally better on auction days. Despite generally better liquidity on Treasury auction days, liquidity costs are still quite large relative to the observed price pressure effect, so that returns from a trading strategy that seeks to exploit the price pressure effect are only significantly positive for one of the three notes examined.

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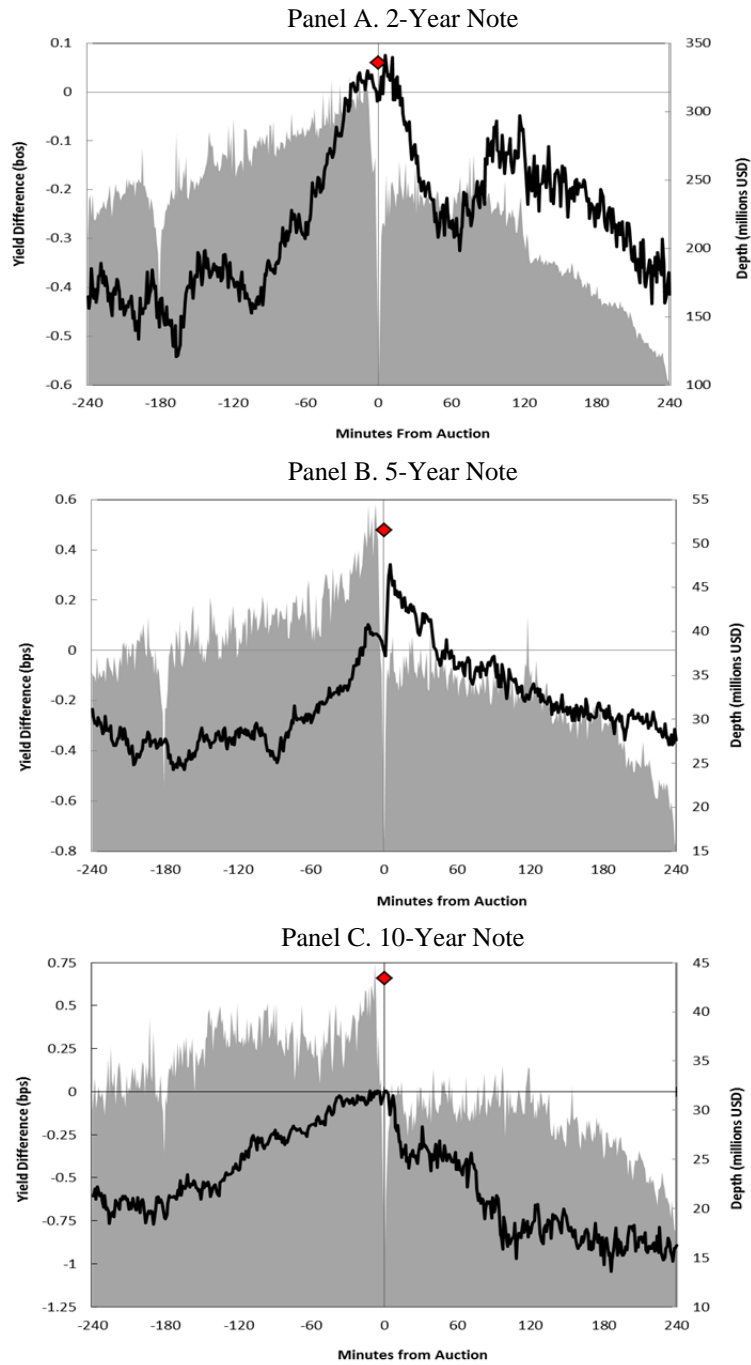
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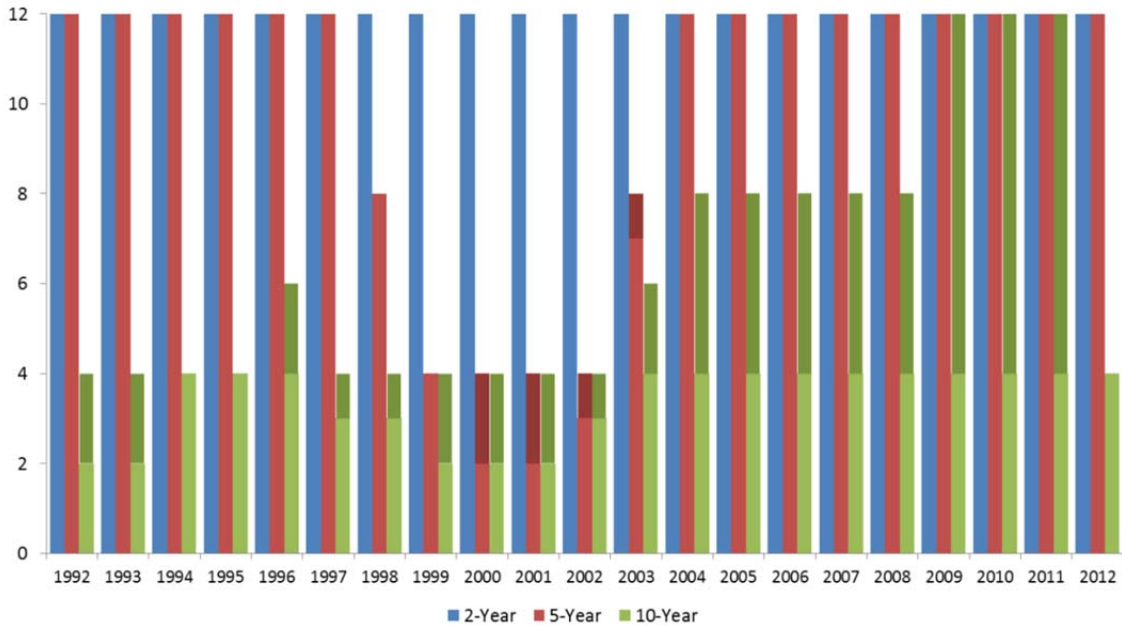
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Figure 1. Yields, liquidity, and underpricing around Treasury auctions



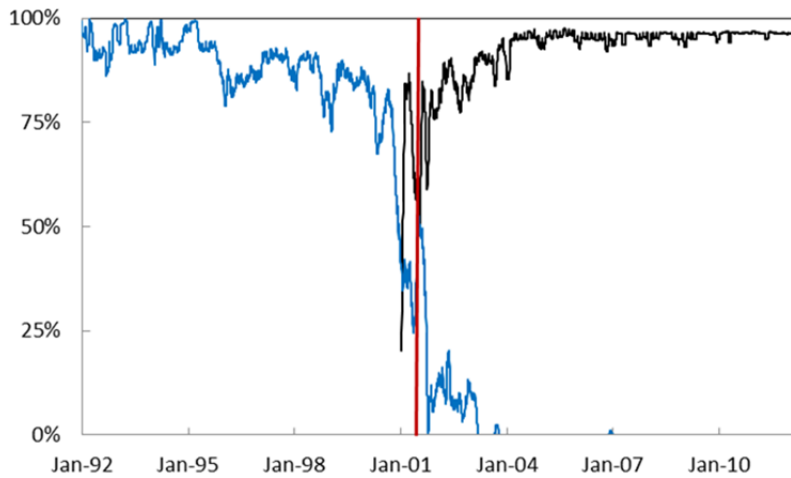
Notes: Panels A-C above show average yield change (black line), first-tier depth (shaded grey), and underpricing (red diamond) in one-minute intervals for the eight hour window around auction time from January 1, 1992 to December 31, 2012. Yield change is calculated using the difference of on-the-run mid-quotes (the average of the best bid and ask quotes) t minutes from auction and at the time of auction, where t ranges from -240, or four hours before auction, and 240, or four hours after auction. Depth is calculated as the average of depth at the best bid and ask prices for the on-the-run security. Between January 1, 1992 and June 30, 2001, depth and yield quotes come from the GovPX platform. Between July 1, 2001 and December 31, 2012, depth and yield quotes come from the BrokerTec platform. Finally, underpricing is calculated as the difference between the winning yield in the primary market and the last observed when-issued yield before auction in the secondary market. The when-issued quotes come from the GovPX platform.

Figure 2. Summary of 2-, 5-, and 10-Year Treasury Note Auctions



Notes: The figure above summarizes all of the auctions for 2-, 5-, and 10-year Treasury notes between January 1, 2012 and December 31, 2012 by maturity and year of auction as reported by Treasury Direct’s historical archive. For the 5-year and 10-year notes, we also include scheduled re-openings in dark red and dark green respectively.

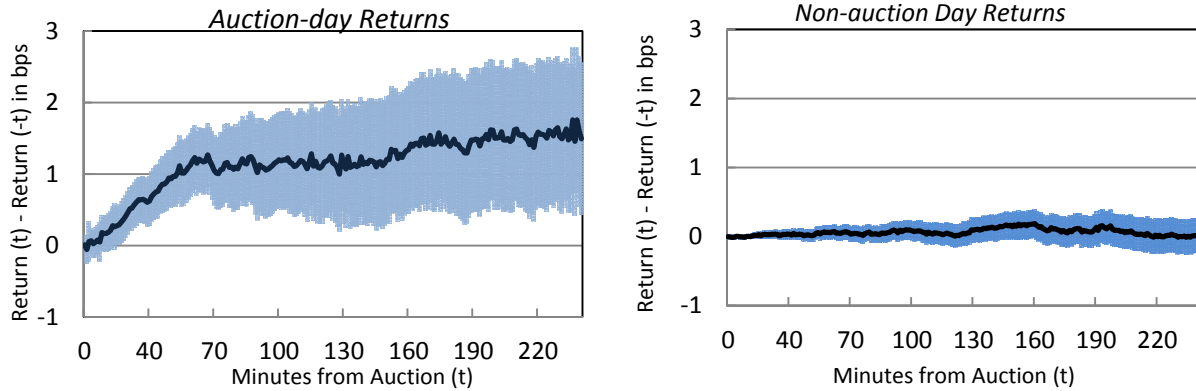
Figure 3. Availability of 10-Year Treasury Note Data



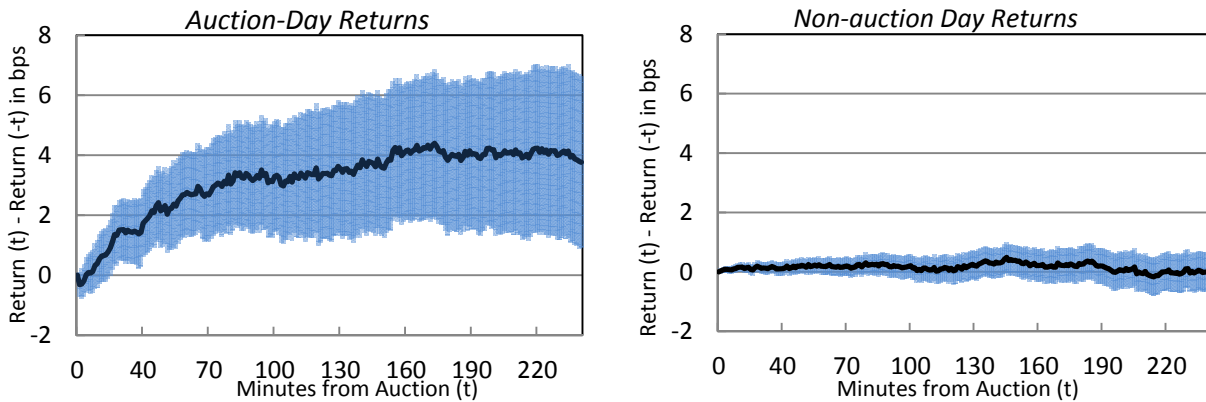
Notes: Figure 3 shows the daily data availability for 2-, 5-, and 10-year notes in GovPX (blue line) and BrokerTec (black line) between January 1, 1992 and December 31, 2012. Data availability is calculated as the percent of minutes between 7am and 5pm in which we observe at least one quote. The red line marks July 1, 2001, the cutoff at which our GovPX sample ends and our BrokerTec sample begins.

Figure 4. Treasury Note Cumulative On-the-run Returns around Subsequent Auctions

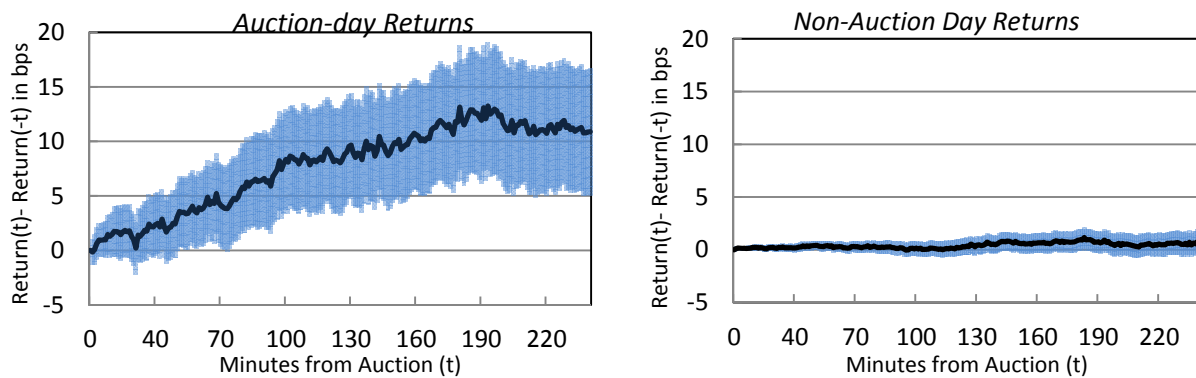
Panel A. 2-Year Note



Panel B. 5-Year Note

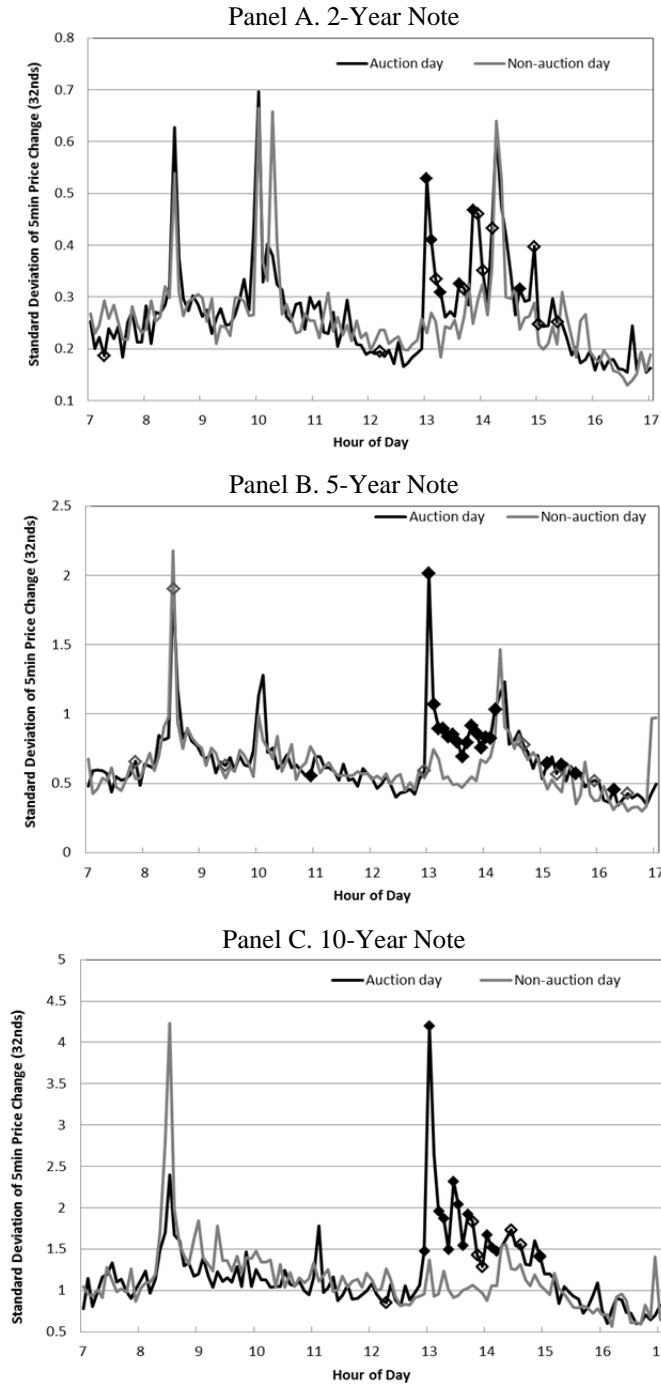


Panel C. 10-Year Note



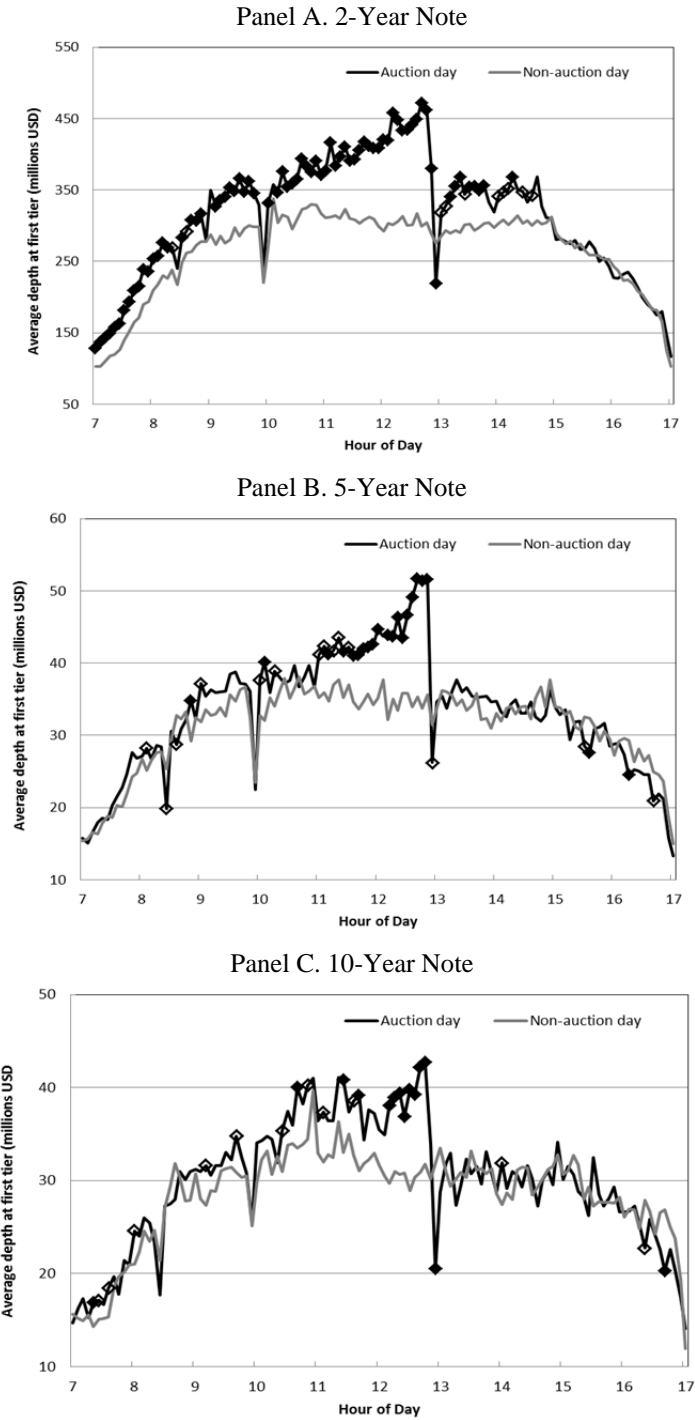
Notes: Panels A-C above show the average return in the eight hour window around time of auction for the 2-, 5-, and 10-year on-the-run Treasury notes between January 1, 1992 and December 31, 2012. In each panel, the left graph represents the average return t minutes from time of auction on days with a Treasury auction of the specific security; the right graph represents the average return t minutes from 1pm, the typical time of auction, on days in which no Treasury note is auctioned. Cumulative return t minutes from time of auction (left graph) or 1pm (right graph) is calculated as: $((\text{mid-price}(t) - \text{mid-price}(0)) / (\text{mid-price}(t) - \text{mid-price}(10))) + ((\text{mid-price}(t) - \text{mid-price}(10)) / (\text{mid-price}(10)))$. The post-auction price is compared to mid-price 10 minutes after auction, instead of mid-price at time of auction, in order to allow any surprise information revealed by the announcement results to settle in the market. Mid-price is calculated as the average of the best bid and ask prices. Returns are expressed in basis points. The shaded blue band shows the 95% confidence interval for the sample mean constructed using a t -test.

Figure 5. Intraday Price Volatility on Auction and Non-auction Days



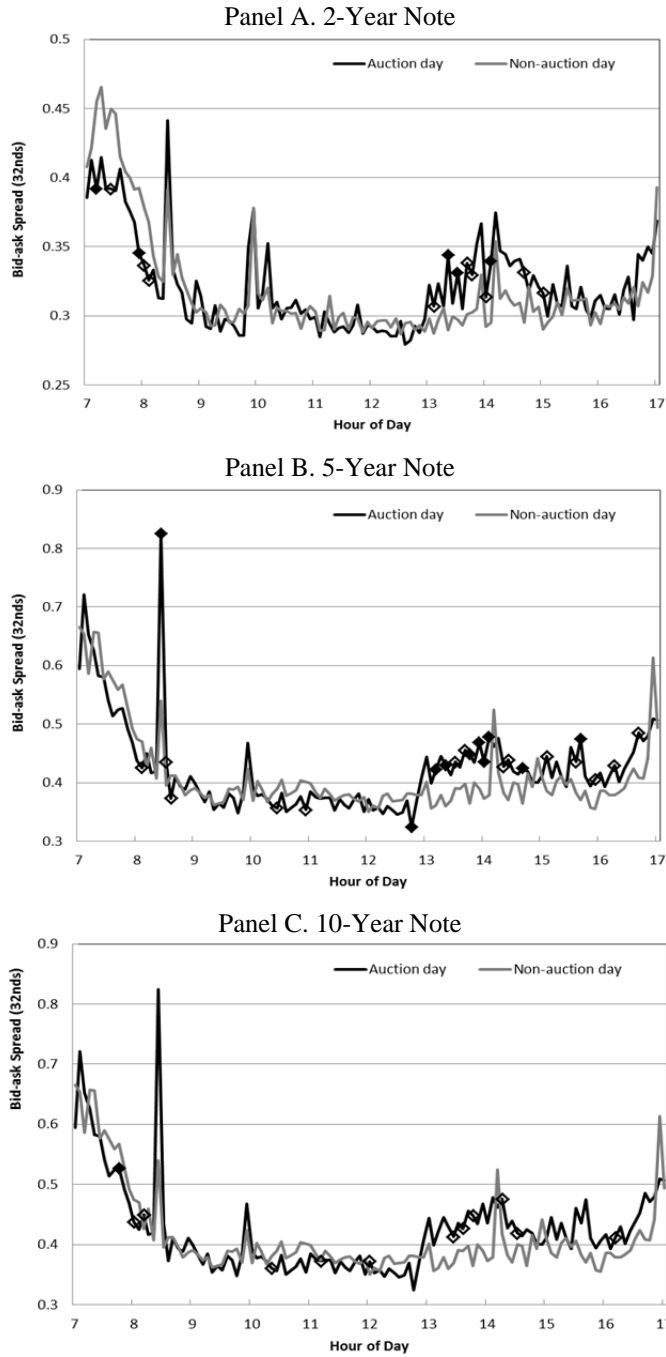
Notes: Panels A- C above show price volatility between 7:00am and 5:00pm on 1pm auction days (black line) and non-auction days (grey line) for 2-, 5-, and 10-year Treasury notes respectively between January 1, 1992 and December 31, 2012. Price volatility is calculated as the standard deviation of five-minute changes in mid-price (the average of the best bid and ask quotes) of the current on-the-run security and is measured in 32nds of a price point. Between January 1, 1992 and June 30, 2001, the quotes come from the GovPX platform. Between July 1, 2001 and December 31, 2012, the quotes come from the BrokerTec platform. An open (shaded) diamond marks a five-minute interval in which auction-day volatility is significantly different from non-auction volatility at the 95% (99%) confidence level using a Brown and Forsythe F-test.

Figure 6. First-tier Depth on Auction and Non-auction Days



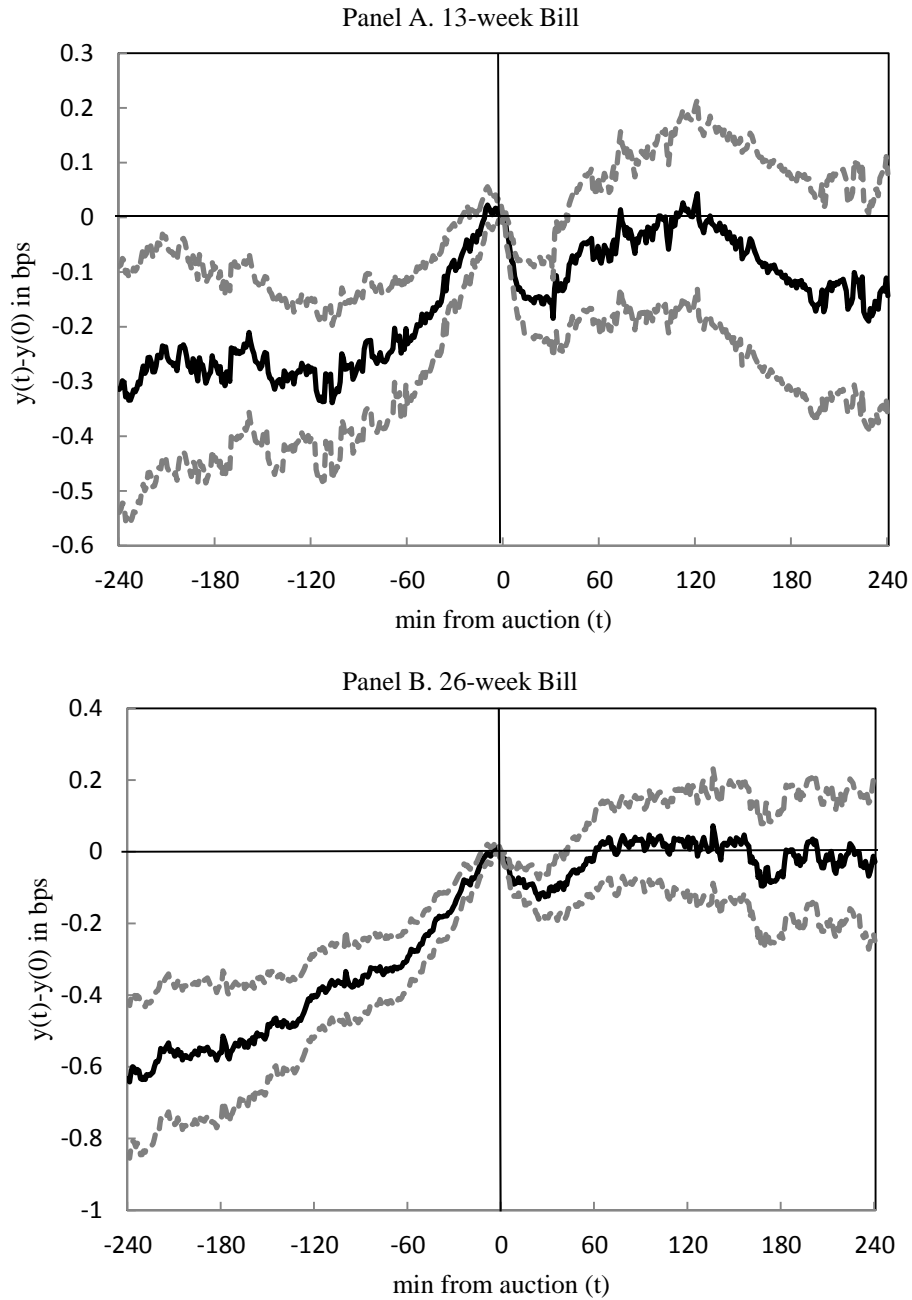
Notes: Panels A- C above show average depth at the first tier between 7:00am and 5:00pm on 1pm auction days (black line) and non-auction days (grey line) for 2-, 5-, and 10-year Treasury notes respectively between January 1, 1992 and December 31, 2012. First tier depth is calculated as the average of depth at the best bid and ask prices across trading days and is measured in millions USD. Between January 1, 1992 and June 30, 2001, observations come from the GovPX platform. Between July 1, 2001 and December 31, 2012, observations come from the BrokerTec platform. An open (shaded) diamond marks a five-minute interval in which auction-day depth is significantly different from non-auction depth at the 95% (99%) confidence level using a two-sample t-test.

Figure 7. Bid-Ask Spread on Auction and Non-auction Days



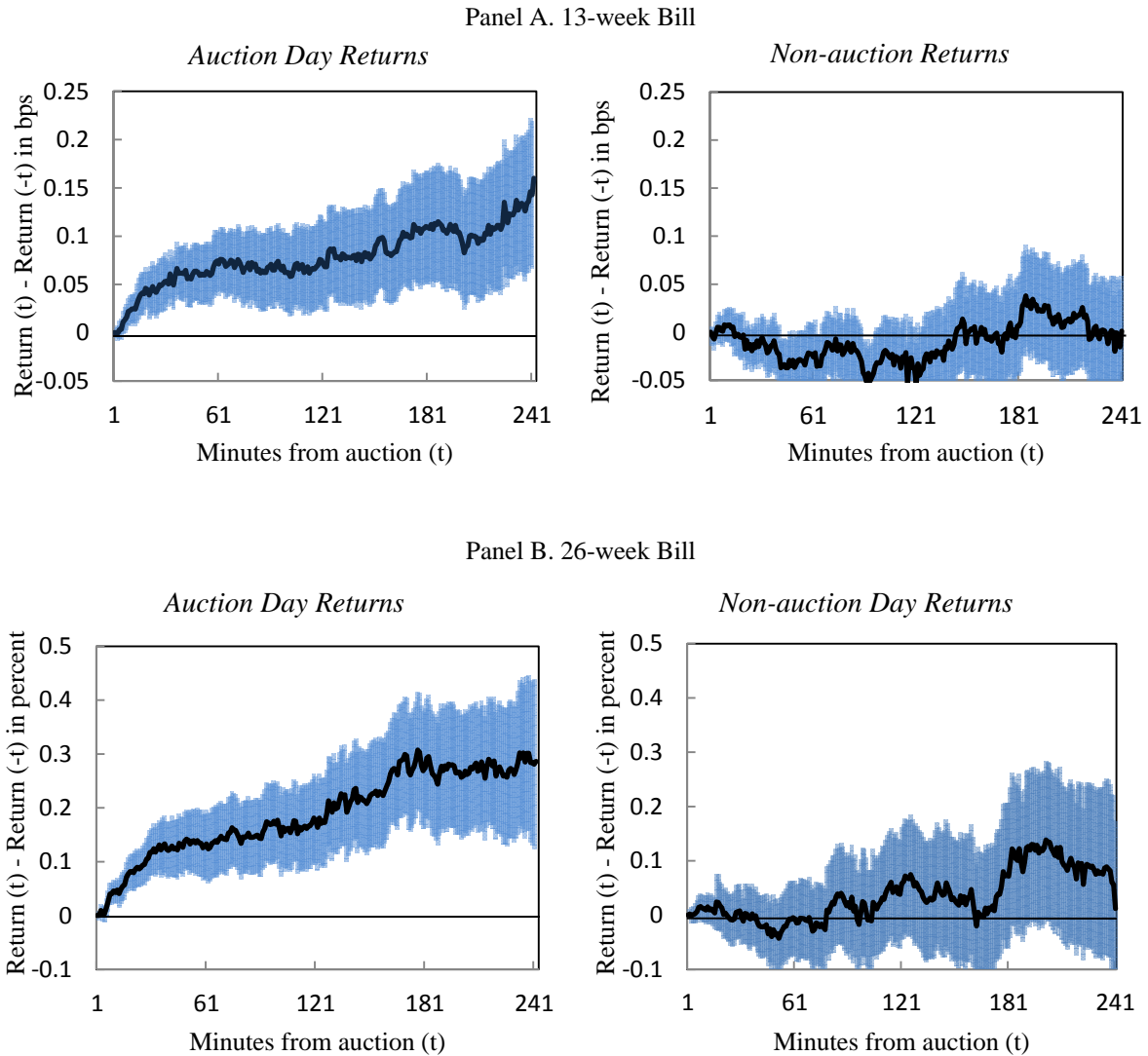
Notes: Panels A- C above show average depth at the first tier between 7:00am and 5:00pm on 1pm auction days (black line) and non-auction days (grey line) for 2-, 5-, and 10-year Treasury notes respectively between January 1, 1992 and December 31, 2012. Bid-ask spread is calculated as the difference of the best bid and ask prices across trading days and is measured in 32nds of a price point. Between January 1, 1992 and June 30, 2001, observations come from the GovPX platform. Between July 1, 2001 and December 31, 2012, observations come from the BrokerTec platform. An open (shaded) diamond marks a five-minute interval in which auction-day spread is significantly different from non-auction spread at the 95% (99%) confidence level using a two-sample t-test.

Figure 8. Yield Changes around Subsequent Auction for On-the-run Treasury Bills



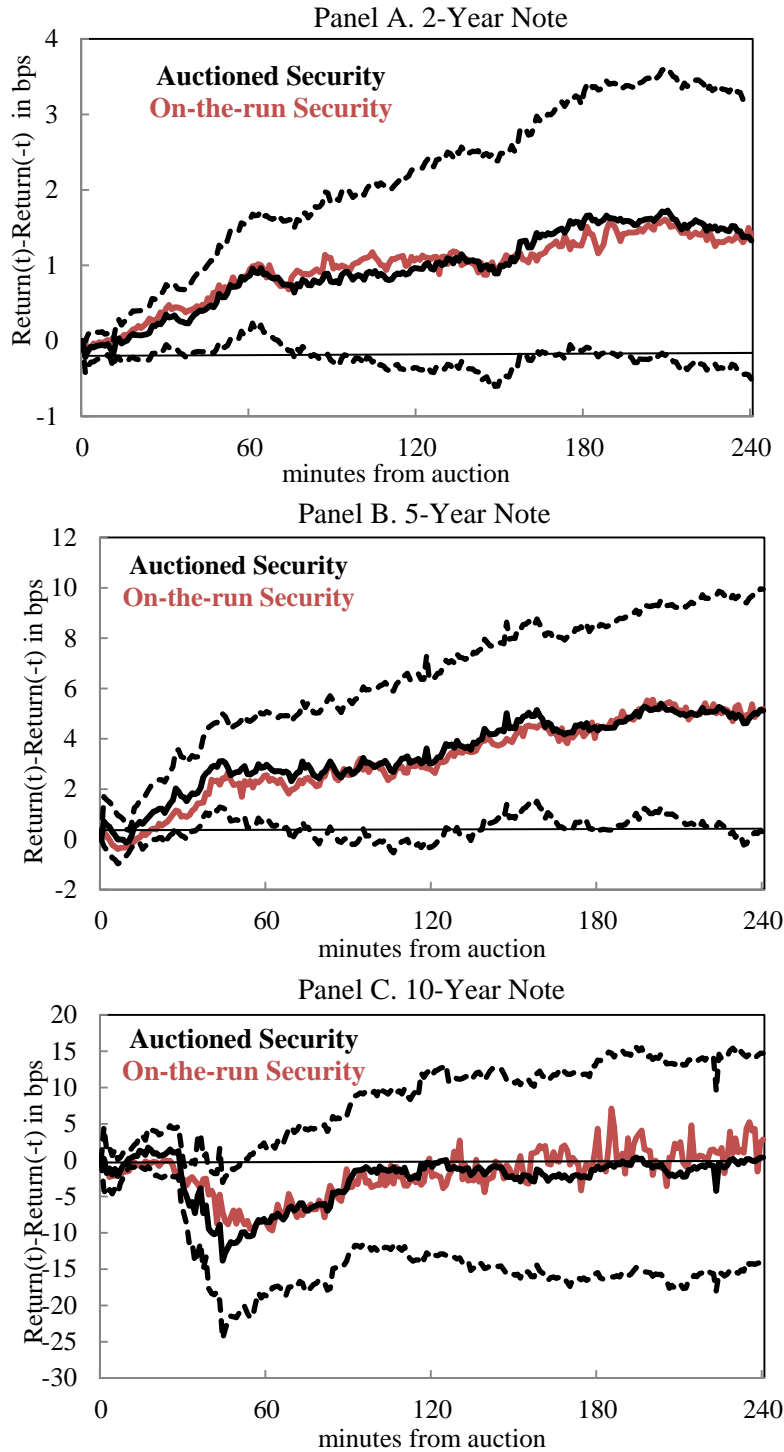
Notes: Panels A-B above show average yield change for the 13- and 26-week on-the-run Treasury bills in one-minute intervals for the eight hour window around auction time from January 1, 1992 to December 31, 2011. Yield change is calculated using the difference of on-the-run 13- or 26-week bill mid-quotes (the average of the best bid and ask quotes) t minutes from auction and at the time of auction, where t ranges from -240, or four hours before auction, and 240, or four hours after auction. The quotes come from the GovPX platform. The dotted grey lines indicate a 95% confidence interval around the sample mean.

Figure 9. Cumulative Returns around Subsequent Auction for On-the-run Treasury Bills



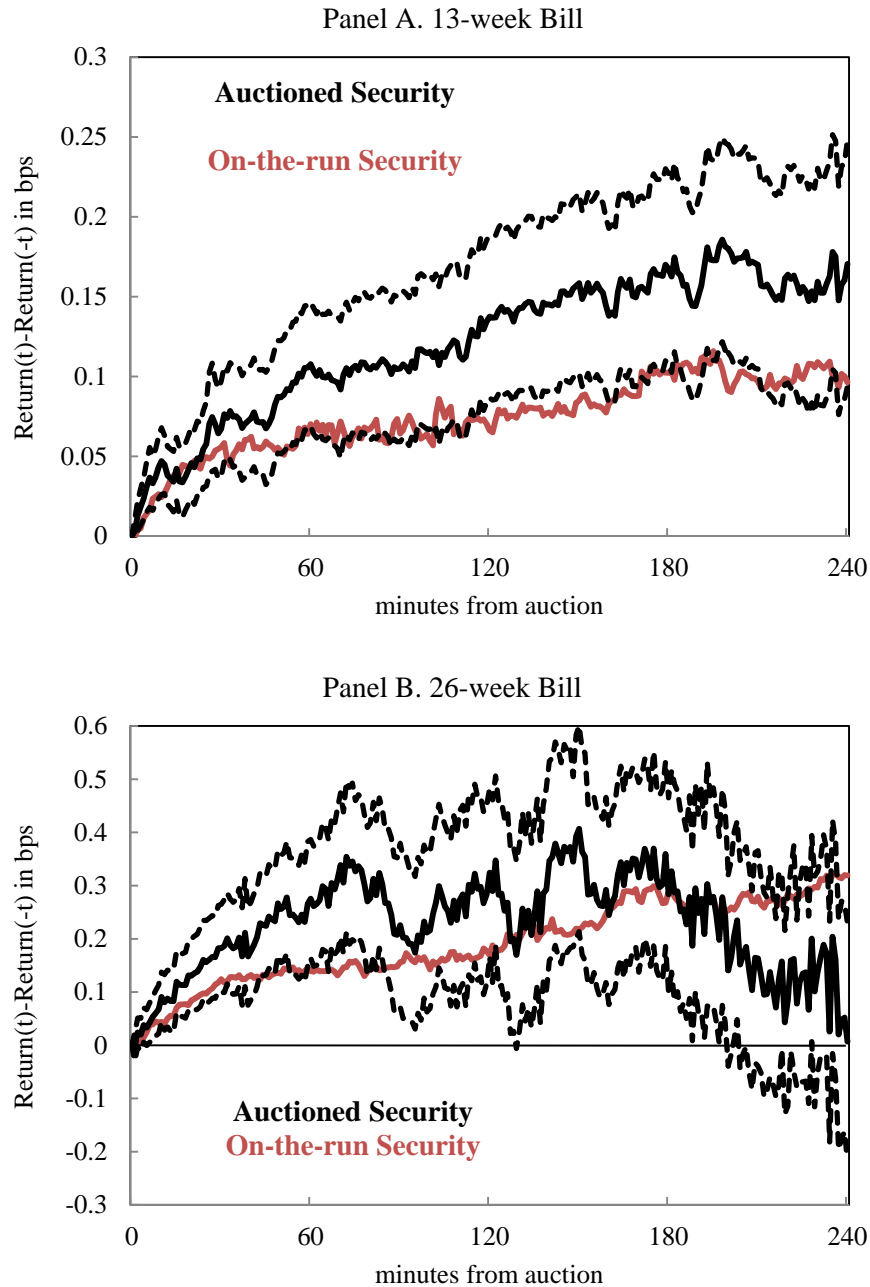
Notes: Panels A-B above show the average return in the eight hour window around time of auction for the 13- and 26-week year on-the-run Treasury bills between January 1, 1992 and June 30, 2001. In each panel, the left graph represents the average return t minutes from time of auction on days with a Treasury auction of the specific security; the right graph represents the average return t minutes from 1pm, the typical time of auction, on the day following auction. This tends to fall on Fridays, the only day of the week with no other Treasury auctions. Cumulative return t minutes from time of auction (left graph) or 1pm (right graph) is calculated as: $((\text{mid-price}(t) - \text{mid-price}(0)) / (\text{mid-price}(t))) + ((\text{mid-price}(t) - \text{mid-price}(10)) / (\text{mid-price}(10)))$. The post-auction price is compared to mid-price 10 minutes after auction, instead of mid-price at time of auction, in order to allow any surprise information revealed by the announcement results to settle in the market. Mid-price is calculated as the average of the best bid and ask prices. Returns are expressed in basis points. All quotes come from the GovPX platform. The shaded blue band shows the 95% confidence interval for the sample mean constructed using a t-test.

Figure 10. When-issued Returns around Subsequent Auction for Notes



Notes: Panels A-C above compares average returns in the eight hour window around auction for the 2-, 5-, and 10-year auctioned (black line) and on-the-run (red line) Treasury notes between January 1, 1992 and June 30, 2001. Cumulative return t minutes from time of auction (left graph) or 1pm (right graph) is calculated as: $((\text{mid-price}(-t) - \text{mid-price}(0)) / (\text{mid-price}(-t))) + ((\text{mid-price}(t) - \text{mid-price}(10)) / (\text{mid-price}(10)))$. The post-auction price is compared to mid-price 10 minutes after auction, instead of mid-price at time of auction, in order to allow any surprise information revealed by the announcement results to settle in the market. Mid-price is calculated as the average of the best bid and ask prices. All quotes come from the GovPX platform. The dotted lines show the 95% confidence interval for the when-issued mean constructed using a t-test.

Figure11. When-issued Returns around Subsequent Auction for Notes



Notes: Panels A-C above compares average returns in the eight hour window around auction for the 13- and 26-week auctioned (black line) and on-the-run (red line) Treasury bills between January 1, 1992 and June 30, 2001. Cumulative return t minutes from time of auction (left graph) or 1pm (right graph) is calculated as: $((\text{mid-price}(t) - \text{mid-price}(0)) / (\text{mid-price}(t) - \text{mid-price}(10))) + ((\text{mid-price}(t) - \text{mid-price}(10)) / (\text{mid-price}(t) - \text{mid-price}(10)))$. The post-auction price is compared to mid-price 10 minutes after auction, instead of mid-price at time of auction, in order to allow any surprise information revealed by the announcement results to settle in the market. Mid-price is calculated as the average of the best bid and ask prices. Returns are expressed in basis points. All quotes come from the GovPX platform. The dotted lines show the 95% confidence interval for the when-issued mean constructed using a t-test.

Table 1. Summary of Intraday Quotes

Panel A. Mid-Prices (USD)				
Security	Mean	Min.	Max.	Std. Dev.
2-year note	99.97	98.18	102.04	0.49
5-year note	99.96	96.33	105.17	1.48
10-year note	100.22	88.98	111.71	3.42
13-week bill	98.91	98.51	99.39	0.22
26-week bill	97.7	96.85	98.66	0.46
Panel B. Mid-Yields (Percent)				
Security	Mean	Min.	Max.	Std. Dev.
2-year note	3.56	0.21	7.61	2.11
5-year note	4.13	0.55	7.86	1.95
10-year note	4.23	1.46	7.97	1.58
13-week bill	4.69	2.62	6.43	0.96
26-week bill	4.87	2.80	6.66	0.99

Notes: Panels A-B above shows summary statistics for mid-yields and mid-prices respectively for on-the-run notes and bills between January 1, 1992 and December 31, 2012. Panel A presents summaries of mid-prices, calculated as the average of the daily bid and ask prices, in percent of par price. Panel B presents summaries of mid-yields, calculated as the average of the daily bid and ask yields, in percent of par. The statistics are calculated over sample of one-minute quotes observed in the eight hour window around time of auction on auction days. Between January 1, 1992 and June 30, 2001, observations come from the GovPX platform. Between July 1, 2001 and December 31, 2012, observations come from the BrokerTec platform.

Table 2. Summary of Intraday Liquidity and Volatility

Panel A. 2- Year Note				
Variable	Mean	Min.	Max.	Std. Dev.
<i>All Observations:</i>				
Depth (mil. USD)	213.92	1.00	6499.00	354.86
Bid-ask Spread (32nds)	0.33	0.13	10.50	0.28
<i>5-Minute Intervals:</i>				
Price Volatility (32nds)	1.82	0.00	5.86	0.84
Depth (mil. USD)	213.92	82.14	325.48	57.48
Bid-ask Spread (32nds)	0.35	0.26	0.78	0.08
Panel B. 5-Year Note				
Variable	Mean	Min.	Max.	Std. Dev.
<i>All Observations:</i>				
Depth (mil. USD)	33.27	1.00	517.00	37.89
Bid-ask Spread (32nds)	0.41	0.25	18.00	0.39
<i>5-Minute Intervals:</i>				
Price Volatility (32nds)	4.46	0.00	16.13	2.07
Depth (mil. USD)	33.27	13.31	51.66	8.16
Bid-ask Spread (32nds)	0.41	0.31	0.78	0.08
Panel C. 10-Year Note				
Variable	Mean	Min.	Max.	Std. Dev.
<i>All Observations:</i>				
Depth (mil. USD)	21.16	1.00	500.00	25.51
Bid-ask Spread (32nds)	0.75	0.50	26.00	0.67
<i>5-Minute Intervals:</i>				
Price Volatility (32nds)	7.92	0.00	33.61	3.68
Depth (mil. USD)	16.01	1.00	42.73	12.58
Bid-ask Spread (32nds)	0.75	0.62	1.43	0.11

Notes: Panels A-C above summarizes intraday first-tier depth, bid-ask spread, and price volatility for the on-the-run 2-, 5-, and 10-year Treasury notes for all auction days between January 1, 1992 and December 31, 2012. The section marked “All Observations” shows summaries for 5-minute snapshots between 7:00 am and 5:00pm. In the section marked “5-minute Intervals”, we take the average (for spread and depth) or standard deviation (for volatility) of 5-minute intervals first across all auction days. Then, we report summaries across the 5-minute intervals. First tier depth is calculated as the average of depth at the best bid and ask prices across trading days and is measured in millions USD. Bid-ask spread is calculated as the difference of the best bid and ask prices across trading days and is measured in 32nds of a price point. Price volatility is calculated as the standard deviation of five-minute changes in mid-price (the average of the best bid and ask quotes) of the current on-the-run security and is measured in 32nds of a price point. Between January 1, 1992 and June 30, 2001, the quotes come from the GovPX platform. Between July 1, 2001 and December 31, 2012, the quotes come from the BrokerTec platform.

Table 3. Summary of Explanatory Variables

Variable	mean	standard deviation	Sample
2Y Depth (billions USD)	2.84	1.75	Aug 1994-Dec 2012
2Y Price Impact (32nds/billion USD)	0.54	0.61	Jan 1992-Dec 2012
2Y Spread (32nds)	0.27	0.02	Jan 1992-Dec 2012
2Y Price Volatility (32nds)	0.27	0.10	Jan 1992-Dec 2012
5Y Depth (billions USD)	0.64	0.38	Aug 1994-Dec 2012
5Y Price Impact (32nds/billion USD)	2.95	1.66	Jan 1992-Dec 2012
5Y Spread (32nds)	0.31	0.08	Jan 1992-Dec 2012
5Y Price Volatility (32nds)	0.67	0.25	Jan 1992-Dec 2012
10Y Depth (billions USD)	0.59	0.32	Aug 1994-Dec 2012
10Y Spread (32nds)	0.57	0.05	Jan 1992-Dec 2012
10Y Price Impact (32nds/billion USD)	7.40	4.31	Jan 1992-Dec 2012
10Y Price Volatility (32nds)	1.14	0.45	Jan 1992-Dec 2012
MOVE Index	98.42	28.42	Jan 1992-Dec 2012
Aaa-Baa Spread (%)	1.07	0.52	Jan 1992-Dec 2012
Yield Curve Fitting Error (bps)	2.87	2.97	Jan 1992-Dec 2012
VIX Index	20.35	8.81	Jan 1992-Dec 2012

Notes: The table above summarizes key explanatory variables used to explain supply effects between January 1, 1992 and December 31, 2012. The variables are only measured as of the day preceding auction day. The Merrill Lynch Option Volatility Estimate (MOVE) and Chicago Board Options Exchange Market Volatility (VIX) indices come from Bloomberg. Moody's Baa-Aaa spread from the U.S. Economics Database in Haver. Yield curve errors come from the MFMA website. First tier depth, price impact, bid-ask spread, and price volatility come from the GovPX platform January 1, 1992 and June 30, 2001. From July 1, 2012 onwards, they come from the BrokerTec Platform/ First tier depth is calculated by taking the average of the depth at the best bid and ask prices and then averaging across the trading day. Bid-ask spread is calculated by taking the difference of the best bid and ask prices and then averaging across the trading day. Price impact is the weekly coefficient on a regression of 5-minute midprice changes on 5-minute net order flows (defined as buy-initiated volume minus sell-initiated volume). Price volatility is calculated as the daily standard deviation of 5-minute midprice changes. Depth was not recorded on the GovPX platform before July 1994, so its sample is limited to July 1994 through December 2012 only.

Table 4. Treasury Note On-the-run Yields Around Subsequent Auctions

t	2-year note		5-year note		10-year note	
	Mean	t-value	Mean	t-value	Mean	t-value
-180	-0.45***	-2.56	-0.36*	-1.97	-0.71***	-3.32
-150	-0.42***	-3.15	-0.32**	-2.05	-0.56***	-2.90
-120	-0.43***	-3.77	-0.33**	-2.33	-0.44**	-2.54
-90	-0.40***	-4.40	-0.39***	-4.05	-0.26*	-1.79
-60	-0.30***	-4.18	-0.29***	-3.50	-0.17	-1.59
-30	-0.08	-1.58	-0.14**	-2.04	-0.02	-0.27
30	-0.15*	-1.67	0.09	0.67	-0.28	-1.34
60	-0.32**	-2.48	-0.07	-0.42	-0.42*	-1.70
90	-0.18	-1.02	-0.05	-0.25	-0.73**	-2.53
120	-0.18	-0.85	-0.14	-0.61	-0.81***	-2.66
150	-0.27	-1.17	-0.22	-0.92	-0.79**	-2.56
180	-0.29	-1.23	-0.27	-1.05	-0.10***	-3.18
No. Obs	252		214		142	

Notes: The table above shows average yield changes from t minutes from auction and the yield at auction on the secondary market for the on-the-run 2-, 5-, or 10-year Treasury notes between January 1, 1992 and December 31, 2012. We take the average of the best bid and ask prices to get a mid-price and then convert prices into yields expressed as basis points. Between January 1, 1992 and June 30, 2001, quotes come from the GovPX platform. Between July 1, 2001 and December 31, 2012, quotes come from the BrokerTec platform. Standard errors shown in parentheses. *, **, and *** denote significance at the 90, 95, and 99% confidence level using a t-test of zero mean respectively.

Table 5. Treasury Note On-the-run Cumulative Returns Around Subsequent Auctions

t	2-year note		5-year note		10-year note	
	Mean	t-value	Mean	t-value	Mean	t-value
30	0.42**	2.09	0.19	0.27	2.61	1.55
60	1.13***	4.17	1.50*	1.76	5.21**	2.77
90	1.07***	2.81	1.92*	1.90	8.32***	4.29
120	1.13**	2.50	1.99*	1.66	10.37***	4.89
150	1.20***	2.43	2.30*	1.87	11.33***	4.65
180	1.37***	2.57	2.64**	2.00	14.11***	5.31
210	1.57***	2.90	2.89**	2.04	12.95***	4.72
240	1.49**	2.58	2.50*	1.66	12.51***	4.73
No. Obs	252		214		140	

Notes: The table above shows average cumulative returns for the on-the-run 2-, 5-, and 10-year Treasury notes in the eight hour window surrounding auction between January 1, 1992 and December 31, 2012. Cumulative return t minutes from time of auction, or return(t), is calculated as: $((\text{mid-price}(-t) - \text{mid-price}(0)) / (\text{mid-price}(-t) + (\text{mid-price}(t) - \text{mid-price}(10)) / (\text{mid-price}(10))))$. The post-auction price is compared to mid-price 10 minutes after auction, instead of mid-price at time of auction, in order to allow any surprise information revealed by the announcement results to settle in the market. Mid-price is calculated as the average of the best bid and ask prices. Returns are expressed in basis points. Between January 1, 1992 and June 30, 2001, quotes come from the GovPX platform. Between July 1, 2001 and December 31, 2012, quotes come from the BrokerTec platform. Standard errors shown in parentheses. *, **, and *** denote significance at the 90, 95, and 99% confidence level using a t-test of zero mean respectively.

Table 6. Returns from Simple Trading Strategy on the BrokerTec Platform

Minutes from auction	2-Year Return	5-Year Return	10-Year Return
t = 60	-0.006*** (0.002)	0.002 (0.007)	-0.013 (0.017)
t = 120	-0.006 (0.004)	0.010 (0.011)	0.047* (0.025)
t = 180	-0.004 (0.005)	0.017 (0.012)	0.083*** (0.029)
t = 240	-0.003 (0.005)	0.016 (0.015)	0.056* (0.030)
<i>Number of Obs:</i>	<i>256</i>	<i>200</i>	<i>133</i>

Notes: The table above shows returns from a simple trading strategy on the in which an investor shorts the on-the-run 2-, 5-, or 10-year Treasury note t minutes before auction then buys back the note at time of auction. After auction, the investor buys the note 10 minutes after auction (allowing any surprise information from the auction to absorb) and then sells back the note t minutes from auction. The reported average returns are the average daily returns across all auctions between January 1, 1992 and December 31, 2012. Between January 1, 1992 and June 30, 2001, quotes come from the GovPX platform. Between July 1, 2001 and December 31, 2012, quotes come from the BrokerTec platform. Standard errors shown in parentheses. *, **, and *** denote significance at the 90, 95, and 99% confidence level using a t-test of zero mean respectively.

Table 7. Explaining Supply Effects using General Market Variables

DEPENDENT VARIABLE:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	2-Year Supply Effect (bps)				5-Year Supply Effect (bps)				10-Year Supply Effect (bps)			
MOVE index /100	1.300 (1.512)				7.265* (3.987)				26.880*** (8.194)			
Yield curve fitting error (bps)		0.407** (0.173)				0.775* (0.435)				1.408* (0.769)		
VIX index			0.038 (0.0440)				0.233* (0.124)				0.714*** (0.261)	
Baa-Aaa spread (bps)				0.0127 (0.009)				0.0271 (0.022)				0.101** (0.045)
Constant	-0.186 (1.578)	-0.015 (0.624)	0.354 (0.989)	-0.098 (0.938)	-3.885 (4.119)	1.196 (1.615)	-1.198 (2.644)	0.744 (2.386)	-18.09** (8.445)	4.468 (3.234)	-6.515 (5.980)	-2.054 (5.253)
Observations	250	250	250	250	210	210	210	210	141	141	141	141
R-squared	0.003	0.022	0.003	0.008	0.016	0.015	0.017	0.007	0.072	0.024	0.051	0.035

Notes: The table above shows results from regressing supply effects around auction on measures of market conditions for the 2-, 5-, and 10-year on-the-run notes respectively between January 1, 1992 and December 31, 2012. Supply effects are measured by taking the average of cumulative returns in the ten minute interval $t=[110,120]$ minutes from auction. Cumulative return t minutes from time of auction is calculated as: $((\text{mid-price}(t)-\text{mid-price}(0))/(\text{mid-price}(t)))+((\text{mid-price}(t)-\text{mid-price}(10))/(\text{mid-price}(10)))$, where midprice is the average of the best bid and ask prices. Between January 1, 1992 and June 30, 2001, quotes come from the GovPX platform. Between July 1, 2001 and December 31, 2012, quotes come from the BrokerTec platform. The market conditions include the Merrill Lynch Option Volatility Estimate (MOVE) Index, the yield curve fitting error, the Chicago Board Options Exchange Market Volatility Index, and the difference between the Aaa and Baa corporate bonds yields as reported by Moody's. The MOVE and VIX indices come from Bloomberg, the yield curve fitting error comes from the Gurkaynak, Sack, and Wright (1961) model at the Board of Governors, and the Baa-Aaa spread comes from Haver's financial database. All independent variables are measured as of the day preceding auction. Standard errors are shown in parentheses. *, **, and *** denote significance at the 90, 95, and 99% confidence level respectively.

Table 8. Explaining Supply Effects using Platform Liquidity Measures

DEPENDENT VARIABLE:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	2-Year Supply Effect (bps)				5-Year Supply Effect (bps)				10-Year Supply Effect (bps)			
1st Tier Depth (billions USD)	-0.403 (1.975)				-56.31 (52.86)				-165.8 (164.8)			
Bid-Ask Spread (32nds)		1.007 (2.706)				2.808 (2.145)				11.94* (6.351)		
Price Impact (32nds/billion net flow)			1.323 (24.18)				39.84 (33.40)				93.90** (40.43)	
Price Volatility (32nds)				-1.060 (1.903)				9.145*** (3.427)				1.098 (5.117)
Constant	1.155* (0.629)	0.796 (0.851)	1.075 (0.836)	1.387*** (0.531)	4.608** (2.032)	1.989 (1.413)	0.0608 (2.606)	-2.305 (2.297)	12.79** (5.312)	-0.989 (5.418)	-3.979 (5.138)	7.366 (6.168)
Observations	219	250	250	250	180	210	210	210	130	141	141	141

Notes: The table above shows results from regressing supply effects around auction on measures of market conditions for the 2-, 5-, and 10-year on-the-run notes respectively between January 1, 1992 and December 31, 2012. Supply effects are measured by taking the average of cumulative returns in the ten minute interval $t=[110,120]$ minutes from auction. Cumulative return t minutes from time of auction is calculated as: $((\text{mid-price}(-t)-\text{mid-price}(0))/(\text{mid-price}(-t)))+((\text{mid-price}(t)-\text{mid-price}(10))/(\text{mid-price}(10)))$, where midprice is the average of the best bid and ask prices. First tier depth is calculated by taking the average of the depth at the best bid and ask prices and then averaging across the trading day. Bid-ask spread is calculated by taking the difference of the best bid and ask prices and then averaging across the trading day. Price impact is the weekly coefficient on a regression of 5-minute midprice changes on 5-minute net order flows (defined as buy-initiated volume minus sell-initiated volume). Price volatility is calculated as the daily standard deviation of 5-minute midprice changes. All liquidity measures are measures as of the day before auction, except for price impact, which is measured for the week preceding auction. Between January 1, 1992 and June 30, 2001, all observations come from the GovPX platform. Between July 1, 2001 and December 31, 2012, all observations come from the BrokerTec platform. Depth was not recorded on the GovPX platform before July 1994, so its sample is limited to July 1994 through December 2012 only. Standard errors are shown in parentheses. *, **, and *** denote significance at the 90, 95, and 99% confidence level respectively.

Table 9. Treasury Bill On-the-run Yields Around Subsequent Auctions

t	13-week bill		26-week bill	
	Mean	t-value	Mean	t-value
-180	-0.26***	-2.98	-0.56***	-5.94
-150	-0.26***	-3.57	-0.48***	-6.43
-120	-0.28***	-4.25	-0.40***	-6.81
-90	-0.26***	-3.84	-0.37***	-6.97
-60	-0.23***	-3.97	-0.29***	-6.79
-30	-0.10**	-2.41	-0.15***	-4.98
30	-0.15***	-4.12	-0.12***	-3.93
60	-0.08	-1.12	-0.01	-0.11
90	-0.02	-0.24	0.04	0.60
120	0.03	0.34	0.04	0.55
150	-0.07	-0.71	0.02	0.21
180	-0.12	-1.25	-0.06	-0.64
No. Obs	469		465	

Notes: The table above shows average yield changes from t minutes from auction and the yield at auction on the secondary market for the on-the-run 13- and 26-week Treasury bills between January 1, 1992 and December 31, 2011. Yields are measured using the average of the best bid and ask. Quotes are derived from the GovPX platform for the entire sample. Standard errors shown in parentheses. *, **, and *** denote significance at the 90, 95, and 99% confidence level using a t-test of zero mean respectively.

Table 10. Treasury Bill Cumulative On-the-run Returns Around Subsequent Auctions

t	13-week bills		26-week bills	
	Mean	t-value	Mean	t-value
30	0.05***	4.34	0.12***	5.63
60	0.08***	4.54	0.12***	3.87
90	0.06***	3.25	0.16***	4.33
120	0.07***	2.89	0.16***	3.93
150	0.09***	3.57	0.23***	4.64
180	0.11***	3.63	0.29***	5.21
210	0.10***	3.06	0.29***	4.90
240	0.16***	4.12	0.29***	3.56
No. Obs	469		465	

Notes: The table above shows average cumulative returns for the on-the-run 13- and 26-week Treasury bills in the eight hour window surrounding auction between January 1, 1992 and December 31, 2011. Cumulative return t minutes from time of auction, or return(t), is calculated as: $((\text{mid-price}(-t) - \text{mid-price}(0)) / (\text{mid-price}(-t))) + ((\text{mid-price}(t) - \text{mid-price}(10)) / (\text{mid-price}(10)))$. The post-auction price is compared to mid-price 10 minutes after auction, instead of mid-price at time of auction, in order to allow any surprise information revealed by the announcement results to settle in the market. Mid-price is calculated as the average of the best bid and ask prices. Returns are expressed in basis points. Quotes come from the GovPX platform for the entire sample. Standard errors shown in parentheses. *, **, and *** denote significance at the 90, 95, and 99% confidence level using a t-test of zero mean respectively.

Table 11. Treasury Note When-issued Yields Around Subsequent Auctions

t	2-year notes		5-year notes		10-year notes	
	Mean	t-value	Mean	t-value	Mean	t-value
-180	-0.41	-1.30	-0.58*	-1.76	-0.51	-0.75
-150	-0.30	-1.47	-0.56**	-2.25	-0.35	-0.58
-120	-0.43**	-2.32	-0.50**	-2.39	-0.45	-0.71
-90	-0.34**	-2.36	-0.64***	-3.72	-0.25	-0.50
-60	-0.23**	-2.25	-0.52***	-4.13	-0.12	-0.30
-30	-0.04	-0.55	-0.31***	-3.41	-0.11	-0.45
30	-0.25**	-2.49	0.10	0.67	0.32	0.64
60	-0.35**	-2.04	-0.06	-0.25	0.93	1.12
90	-0.39	-1.45	-0.017*	-0.05	0.27	0.38
120	-0.33	-1.01	-0.19	-0.52	0.23	0.27
150	-0.45	-1.24	-0.40	-1.01	0.36	0.39
180	-0.60	-1.65	-0.39	-0.90	0.26	0.25
No. Obs	105		83		19	

Notes: The table above shows average when-issued yield changes from t minutes from auction and the yield at auction on the secondary market for the auctioned 2-, 5-, or 10-year Treasury notes between January 1, 1992 and June 30, 2001. We take the average of the best bid and ask prices to get a mid-price. When-issued quotes come from the GovPX platform. Standard errors shown in parentheses. *, **, and *** denote significance at the 90, 95, and 99% confidence level using a t-test of zero mean respectively.

Table 12. Treasury Note Cumulative When-issued Returns Around Subsequent Auctions

t	2-year notes		5-year notes		10-year notes	
	Mean	t-value	Mean	t-value	Mean	t-value
30	0.35*	1.71	1.67**	1.71	-4.06**	-2.37
60	0.87**	2.31	2.97***	2.31	-8.56	-1.65
90	0.78	1.44	2.79**	1.44	-2.73	-0.54
120	0.96	1.43	3.03*	1.43	-0.94	-0.15
150	1.00	1.31	4.42**	1.31	-2.62	-0.39
180	1.60*	1.83	4.33**	1.83	-0.86	-0.12
210	1.72*	1.79	4.95**	1.79	-1.68	-0.21
240	1.33	1.42	5.12**	1.42	0.37	0.05
No. Obs	105		83		19	

Notes: The table above shows average cumulative returns for the auctioned 2-, 5-, and 10-year Treasury notes in the eight hour window surrounding auction between January 1, 1992 and June 30, 2001. Cumulative return t minutes from time of auction, or return(t), is calculated as: $((\text{mid-price}(-t) - \text{mid-price}(0)) / (\text{mid-price}(-t))) + ((\text{mid-price}(t) - \text{mid-price}(10)) / (\text{mid-price}(10)))$. The post-auction price is compared to mid-price 10 minutes after auction, instead of mid-price at time of auction, in order to allow any surprise information revealed by the announcement results to settle in the market. Mid-price is calculated as the average of the best bid and ask prices. Returns are expressed in basis points. When-issued quotes come from the GovPX platform. Standard errors shown in parentheses. *, **, and *** denote significance at the 90, 95, and 99% confidence level using a t-test of zero mean respectively.

Table 13. Treasury Bill Cumulative When-issued Yields Around Subsequent Auctions

t	13-week bill		26-week bill	
	Mean	t-value	Mean	t-value
-180	-0.44***	-4.86	-0.40**	-2.47
-150	-0.43***	-5.53	-0.57***	-3.72
-120	-0.39***	-5.60	-0.55***	-3.90
-90	-0.32***	-4.78	-0.46***	-4.60
-60	-0.28***	-4.50	-0.40***	-5.93
-30	-0.08***	-1.65	-0.28***	-6.08
30	-0.21***	-4.54	-0.19***	-2.90
60	-0.16**	-2.23	-0.22**	-2.43
90	-0.10	-1.20	-0.21*	-1.78
120	-0.11	-1.19	-0.40***	-3.64
150	-0.20*	-1.96	-0.47***	-4.46
180	-0.20**	-1.98	-0.48***	-4.49
No. Obs	440		402	

Notes: The table above shows average yield changes from t minutes from auction and the when-issued yield at auction on the secondary market for the auctioned 13- and 26-week Treasury bills between January 1, 1992 and June 30, 2001. Yields are measured using the average of the best bid and ask. Quotes are derived from the GovPX platform for the entire sample. Standard errors shown in parentheses. *, **, and *** denote significance at the 90, 95, and 99% confidence level using a t-test of zero mean respectively.

Table 14. Treasury Bill Cumulative When-issued Returns Around Subsequent Auctions

t	13-week bills		26-week bills	
	Mean	t-value	Mean	t-value
30	0.07***	4.45	0.18***	4.33
60	0.11***	5.43	0.28***	4.85
90	0.10***	4.49	0.23***	2.87
120	0.14***	5.29	0.32***	4.03
150	0.16***	5.52	0.41***	4.12
180	0.17***	5.49	0.28***	3.07
210	0.17***	5.10	0.16	1.58
240	0.17***	4.35	0.01	0.06
No. Obs	440		402	

Notes: The table above shows average cumulative returns for the auctioned 13- and 26-week Treasury bills in the eight hour window surrounding auction between January 1, 1992 and June 30, 2001. Cumulative return t minutes from time of auction, or return(t), is calculated as: $((\text{mid-price}(-t) - \text{mid-price}(0)) / (\text{mid-price}(-t))) + ((\text{mid-price}(t) - \text{mid-price}(10)) / (\text{mid-price}(10)))$. The post-auction price is compared to mid-price 10 minutes after auction, instead of mid-price at time of auction, in order to allow any surprise information revealed by the announcement results to settle in the market. Mid-price is calculated as the average of the best bid and ask prices. Returns are expressed in basis points. Quotes come from the GovPX platform for the entire sample. Standard errors shown in parentheses. *, **, and *** denote significance at the 90, 95, and 99% confidence level using a t-test of zero mean respectively

Table A1. Daily Treasury Note Returns Around Subsequent Auctions

t	2-year notes		5-year notes		10-year notes	
	Mean	t-value	Mean	t-value	Mean	t-value
1	1.52	1.55	5.25*	1.89	-3.44	-0.39
2	4.00***	2.99	14.80***	3.81	3.21	0.16
3	6.70***	4.37	20.68***	4.54	16.78*	1.63
4	9.65***	5.19	27.75***	5.47	25.77**	2.12
5	9.84***	4.96	31.22***	5.26	21.43	1.54
6	11.14***	5.03	26.49***	3.84	26.07*	1.75
7	10.36***	4.29	25.68***	3.56	17.33	1.07
8	10.31***	3.90	27.75***	3.95	17.04	1.07
9	10.63***	3.93	22.76***	3.07	19.86	0.98
10	11.64***	4.07	22.45***	2.84	7.40	0.44
No. Obs	247		211		141	

Notes: The table above shows average cumulative returns for the on-the-run 2-, 5-, and 10-year Treasury notes in the ten day window surrounding auction between January 1, 1992 and December 31, 2012. Cumulative return t days from time of auction, or return(t), is calculated as: $((\text{price}(-t) - \text{price}(0)) / (\text{price}(-t))) + ((\text{price}(t) - \text{price}(0)) / (\text{price}(0)))$. Prices come from daily CRSP quotes. Standard errors shown in parentheses. *, **, and *** denote significance at the 90, 95, and 99% confidence level using a t-test of zero mean respectively.