Anticipated and Repeated Shocks in Liquid Markets*

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Abstract

This paper examines how anticipated and frequently repeated shocks are absorbed in liquid financial markets. We show that Treasury security prices in the secondary market decrease significantly in the few days leading up to Treasury auctions and recover shortly thereafter, even though the time and amount of each auction are announced in advance. The issuance cost to the Treasury Department is estimated to be between 9 and 18 basis points of the auction size, or over half a billion dollars for note issuance alone in 2007, most of which can be attributed to the price pressure effect around auction days. These results are linked to dealers' limited risk-bearing capacity and the imperfect capital mobility of end-investors, highlighting the important role of market frictions even in very liquid financial markets.

JEL Classification Numbers: G12.

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I. Introduction

In this paper, we empirically examine how *anticipated and frequently repeated* supply shocks are absorbed in liquid financial markets. In particular, we examine the temporary price impact of Treasury security auctions on the secondary Treasury and repo markets. This may appear as a surprising agenda: Treasury auctions are conducted every month, of which the exact time and amounts are announced in advance, so these events are largely anticipated. Given the size and liquidity of the U.S. Treasury and repo markets, one might expect no appreciable price impact from these anticipated events. In sharp contrast to this conventional view, our evidence reveals significant temporary price effects in both markets around Treasury auctions.

Specifically, we find that Treasury security prices in the secondary market tend to dip in the few days leading up to Treasury auctions and recover shortly thereafter. An intuitive way to describe this price dip and recovery pattern is to compare Treasury returns around auctions: For example, the 5-day cumulative return of an on-the-run 2-year Treasury note before a 2-year note auction is, on average, 8.89 (t = 2.93) basis points lower than the 5-day post-auction return of the same security. [1] This pattern holds true for off-the-run securities, as well as other maturities.

These findings have potentially important implications. First of all, they suggest that the cost of security issuance borne by the Treasury Department is an order of magnitude larger than what is implied by prior research on Treasury auction underpricing. This strand of research compares the auction price with a benchmark price *on the auction day*, and finds the underpricing to be less than 1 basis point of the

[1] An on-the-run Treasury security is the most recently issued security of a given maturity. The first off-the-run and the second off-the-run securities are the second and third most recently issued securities of a given maturity, respectively.

auction size (Goldreich, 2007). Our findings suggest that, due to the price impact resulting from Treasury auctions, these benchmark prices on auction days are already depressed. Therefore, while the traditional approach is appropriate for measuring underpricing in auctions, it does not reflect the total issuance cost borne by the Treasury Department.

To incorporate this price impact into our cost measure, for each n-year note auction (n = 2, 5, 10), we take the average price of the n-year note in the secondary market on the t^{th} day before and t^{th} day after the auction as the benchmark price, with t ranging from 1 to 10. That is, our measure reflects the amount of money the Treasury Department could have saved were it able to issue Treasury securities at the average secondary market price during the several days before and after each auction. For $t = 5$, for example, our estimates of Treasury issuance costs for 2-, 5-, and 10-year notes are 9.07, 16.81, and 18.43 basis points of the auction size, respectively. According to these estimates, the total cost of issuing Treasury notes alone in 2007 is $649 million. While it is by no means clear whether part of the estimated cost can be saved through better designs of the Treasury selling mechanism, recognizing such a cost is a necessary first step to understand and improve the efficiency of Treasury auctions.

Second, our findings suggest that the frictions behind the market's response to demand/supply shocks are important even in very liquid financial markets. In particular, we compute the return of a long-short strategy that exploits these reoccurring swings in Treasury prices around auction days. By going short the on-the-run 2-year note and long a duration-matched portfolio comprising the on-the-run 6-month Treasury bill and 10-year note during the 10 days before each 2-year note auction, and holding the reverse positions during the 10 days after, one can achieve an annualized Sharpe ratio of 0.84, after accounting for bid-ask spreads and repo funding costs. This is comparable to many well-known asset pricing anomalies, such as currency carry trade and momentum in the U.S. stock market. Our evidence that even the Treasury market is unable to quickly absorb these anticipated and repeated shocks suggests that market frictions play a perhaps more important role in the financial system than previously thought. [2]

Our evidence is consistent with the interpretation that Treasury auctions cause temporary price movements in secondary Treasury markets. The underlying mechanism has two ingredients: primary dealers' limited risk-bearing capacity and end-investors' imperfect capital mobility. Primary dealers are expected to participate actively and submit competitive bids in all Treasury auctions. They tend to hedge the risk they are about to acquire in Treasury auctions by short selling similar securities in the secondary market before these auctions, thus exerting downward price pressure in the secondary market. [3] Consistent with this interpretation, we find that the price impact in the secondary market is more pronounced precisely when the auction size is larger, when dealers are more capital constrained, or when interest rates are more volatile. Further, primary dealers' short selling would not have a price impact were there enough end-investors or arbitrageurs to supply liquidity. For one thing, arbitrageurs are unlikely to be able to absorb the entire supply from Treasury auctions, which is in the magnitude of tens of billions of dollars. In addition, major end-investors, including foreign investors, state and local governments, insurance companies, and bond mutual funds are passive

[2] In a recent study, Fleckenstein, Longstaff, and Lustig (2010) provide another piece of evidence on the imperfection of the Treasury markets: the price of a Treasury bond is significantly higher than an inflation-swapped TIPS issue that replicates the cash flows of the Treasury bond.

[3] Primary dealers can also take short positions in the when-issued market. But this can also depress spot Treasury prices, if the counterparties with long positions in the when-issued market hedge their exposures in the secondary Treasury market.

investors, many of whom do not have the intention, or resources, to engage in short-term arbitrage trades.

This interpretation has a number of further predictions. First, it implies that repo rates should be lower before Treasury auctions compared to those after. This is because short positions in the secondary Treasury market are usually established through reverse repo transactions. Specifically, primary dealers lend cash to their counterparties and take Treasury securities as collateral, which they then short-sell in secondary markets. Primary dealers' strong demand for these transactions before auctions implies that they would be willing to accept lower interest rates on their lending, leading to lower repo rates. Consistent with this prediction, we find that the average overnight special repo rate backed by 2-/5-/10-year Treasury notes during the 5 days before auctions of a 2-/5-/10-year notes is, on average, 25/23/32 basis points lower than that during the post-auction 5-day period. Second, auctions of Treasury securities with one maturity should also affect prices of other maturities, and the impact should be stronger if the maturity differential is smaller. Consistent with this prediction, we find a similar pattern in 10-year note returns around both 2-year and 5-year note auctions, even when there is no 10-year note auction in surrounding days. Moreover, relative to 2-year note auctions, 5-year note auctions have a much stronger price impact on 10-year notes.

Our paper is related to the growing literature on the price impact of supply and demand shocks.[4] The contribution of our paper is to provide clean evidence in arguably the most liquid financial markets where the relatively small supply shocks are both well

[4] See, for example, Shleifer (1986), Kaul, Mehrotra, and Morck (2000), Wurgler and Zhuravskaya (2002), Newman and Rierson (2003), Mitchell, Pulvino, and Stafford (2004), Coval and Stafford (2007), Frazzini and Lamont (2008), and Lou (2012).

anticipated and frequently repeated. Our paper is closely related to the findings in Fleming and Rosenberg (2007) that primary dealers take short positions shortly before Treasury auctions, and that the newly issued securities tend to have high returns after auctions. Our paper is also related to studies that examine the permanent impact of bond supply on Treasury yields and spreads, and changes in yields around policy announcements.[5] Our paper differs from these studies in that it examines the temporary price impact around auctions, as well as the spillover effects across maturities and across markets. Our findings are broadly consistent with Vayanos and Vila (2009), where local demand and supply can distort Treasury yields due to market segmentation.

Our results are distinct from the on-the-run premium phenomenon. Motivated by Duffie (1996), several recent studies analyze the on-the-run premium and find that the specialness of an on-the-run security decreases when the next issuance approaches.[6] While this mechanism is consistent with the price decrease of the on-the-run security before the next auction of the same maturity, it cannot explain the post-auction price increase, or the yield/return pattern for off-the-run securities and the spillover effects to other maturities and markets.

[5] See, for example, Simon (1991), Duffee (1996), Krishnamurthy (2002), Kuttner (2006), Greenwood and Vayanos (2010), and Krishnamurthy and Vissing-Jorgensen (2010), Han, Longstaff and Merrill, (2007), Garbade and Rutherford (2007), Gagnon, Raskin, Remache and Sack (2010), D'Amico and King (2011), Krishnamurthy and Vissing-Jorgensen (2011), and Swanson (2011).

[6] See, for example, Jordan and Jordan (1997), Krishnamurthy (2002), Meli (2002), and Goldreich, Hanke, and Nath (2005).

II. Data

A. Institutional background of Treasury auctions

In our sample period of 1980-2008, the U.S. Treasury Department auctioned, on average, $2.35 trillion worth of securities each year; the total amount auctioned was $6.7 trillion in 2008. The participants of these auctions include primary dealers, institutional investors, foreign central banks, the Federal Reserve, and a small number of individual investors. The Treasury Department publishes tentative auction schedules several months in advance and announces the auction size several days before each auction. Immediately after the announcements, dealers and investors start to trading forward contracts on the soon-to-be-issued Treasury security in the "when-issued" market.

In each auction, primary dealers and other competitive bidders submit sealed bids of rate-quantity pairs that specify the amount to be purchased at each minimum yield. Two auction mechanisms have been employed in Treasury auctions: multiple-price and single-price auctions. Under both mechanisms, the clearing price is identified by equating the aggregate demand submitted by competitive bidders to the total issue amount minus the total demand from noncompetitive bidders (i.e., those who submit market orders). The difference between the two mechanisms lies in that, while in multiple-price auctions, competitive bidders pay for their allocated shares at their submitted prices, in single-price auctions, all winning bidders pay the same price. While almost all Treasury auctions in the 1980s were multiple-price auctions, the single-price mechanism is the dominant form in the more recent two decades.[7]

[7] For a more detailed discussion of these two auction mechanisms see, e.g., Goldreich (2007).

B. Data sample

From the U.S. Treasury Department website, we collect detailed information regarding auctions for Treasury notes, with maturities ranging from 2 to 10 years. Such information includes the auction date, issue date, auction mechanism, bids submitted, total tender amount received, total tender amount accepted, lowest and highest winning rates, etc. Our sample spans from January 1980 to June 2008, during which period 2-year Treasury notes are issued on a monthly basis and 10-year notes are issued on a quarterly basis and are frequently reopened in the following months. Our sample also includes these reopened issues. The issuing frequency of 5-year notes varied a few times in this period. In total, we have 332 2-year note auctions, 210 5-year note auctions, and 132 10-year note auctions.[8] We then match our auction data with the CRSP daily U.S. Treasury database to obtain daily Treasury security prices and accrued interest, from which we compute Treasury yields and daily returns. Throughout our analysis, we use the average of the bid and ask prices reported by CRSP as our measure of the security price.

The repo market in the U.S. is very large, with an estimated size of over $10 trillion (Gorton and Metrick (2010)). We obtain daily overnight special repo rates backed by 6-month T-bill, 2-, 5-, and 10-year Treasury notes from Datastream and GovPX. We also obtain daily general collateral (GC) repo rates (repo contracts backed by government general collaterals) and overnight Libor rates from Bloomberg, and AA-rated nonfinancial overnight commercial paper rates and Federal Funds rates from the website of the Federal Reserve Board. From Mueller, Vedolin, and Yen (2011), we

[8] The Treasury also issued 3-, 4-, and 7-year notes during part of our sample period. Their issuance, however, was interrupted in the period of 1998-2003 for 3-year notes, 1990-2008 for 4-year notes, and 1993-2008 for 7-year notes.

obtain the daily model-free estimates of maturity-weighted implied volatility of nearest-to-expiry at-the-money options on the 30-year, 10-year, and 5-year Treasury securities. We obtain the CBOE Volatility Index, VIX, from CBOE website. Finally, following Adrian, Etula, and Muir (2012), we construct the quarterly aggregate leverage growth for broker-dealers from the Federal Reserve Flow of Funds data.

Table I presents some summary statistics for our sample. Panel A shows that the average size of Treasury auctions is well over \$10 billion. Panel B shows that the average daily Treasury note return ranges from 1.96 (for 2-year notes) to 2.31 (for 10-year notes) basis points. Panel C summarizes other main variables. The average option-implied Treasury return volatility is around 8%; the average VIX is about 20%; the average growth rate of the leverage ratio (asset/equity) of broker-dealers is roughly 11% in our sample. The average daily special repo rates backed by 6-month, 2-year, 5-year, and 10-year Treasury securities are 2.88, 2.65, 2.49, and 2.29 basis points, respectively.

III. Price Impact on Secondary Markets

To analyze the impact of Treasury auctions on the secondary Treasury market, we first examine yields-to-maturity of 2-year notes, the most frequently issued Treasury notes, around 2-year note auctions. For each 2-year note auction, we calculate daily yields to maturity of the on-the-run 2-year note during both the 10 days before and 10 days after the auction and compare them with the yield on the auction day. That is, we track the same 2-year note throughout the 20-day window around each auction, and this security is on-the-run before the auction and becomes off-the-run after the auction. Since there is a 2-year note auction almost every month in our sample, these 20-day event windows around auctions cover virtually all trading days in our sample period.

The pattern in Treasury yields around auctions can be easily seen in Figure 1. The upper-left panel plots the time series average of Y(t)-Y(0), where Y(t) is the yield of the on-the-run 2-year note on day t and Y(0) is the yield of the same security on the auction day. There is a clear inverted-V shaped pattern: yields tend to go up before auctions and then decrease afterward. Table II reports the more detailed results. For 2-year notes, the yield difference, Y(t)-Y(0), is negative in the entire 20-day window surrounding the auction, and is statistically significant during the 4 days immediately before the auctions and 6 days after the auctions. The yield of 2-year notes increases, on average, by 2.53 basis points during the 5-day period before the auctions, and decreases by 2.32 basis points during the 5-day period afterward.

These results suggest that 2-year note auctions impact temporarily the price of existing 2-year notes in the secondary market. Another way to see this price impact is to compare 2-year note returns before and after these auctions. This approach effectively integrates the pre- and post-auction impacts into one measure and so increases the statistical power in detecting such price impact. As shown in Panel A of Table III, the return of the on-the-run 2-year note on the day prior to a 2-year note auction is, on average, 3.68 basis points lower than the return of the same note on the day immediately after the auction, with a t-statistic of 3.90. The return difference is positive and statistically significant in the entire 20-day window: The average cumulative return during the 10 days after auctions is 9.20 basis points higher than that during the 10 days before, with a t-statistic of 2.02. The return differential achieves its maximum on day 6, with a point estimate of 10.2 basis points and a t-statistic of 3.62.

The documented yield and return pattern around auctions is not unique to 2-year notes. A very similar pattern exists for other maturities. For example, as shown in

Table II, the yield of the on-the-run 5-/10-year notes increases by 2.67/1.57 basis points during the 5 days before auctions, and decreases by 2.74/2.00 basis points in the 5 days after. Moreover, as shown in Panel A of Table III, the cumulative 5-day return of the on-the-run 5-year Treasury note before a 5-year note auction is, on average, 22.54 ($t =$ 3.67) basis points lower than the 5-day return of the same note after the auction. This 5-day return differential is 23.84 ($t = 1.78$) basis points for 10-year notes.

One potential concern with our Treasury return pattern is the variation in repo funding costs around Treasury auctions. As shown in Krishnamurthy (2002), the on-the-run vs. off-the-run premium can be largely explained by repo specialness. To address this issue, we repeat our analysis in Panel A, but now adjust for repo funding costs when computing Treasury return differentials. Specifically, we subtract the daily Treasury note return by 1/360 of the overnight repo rate on that day. We use special repo rates for on-the-run securities and GC rates for off-the-run securities, as the security in the secondary market becomes off-the-run after the new security is issued. As shown in Panel B, our main results are unaffected by this adjustment. In particular, the return effect around 2-year note auctions is by and large unchanged, despite the shorter sample period due to the availability of repo data. Although there are much fewer 5- and 10-year auctions, the results for 5- and 10-year notes also remain similar, albeit with lower statistical significance due to the smaller sample sizes.

The above results imply a substantial issuance cost for the Treasury Department and, more importantly, this cost has been largely ignored in the literature. Prior literature on Treasury auction underpricing has focused on the difference between the auction price and some benchmark price *on auction days* (e.g., the secondary market price or the forward price in the when-issue market). While this is perhaps a clean measure of auction underpricing due to winner's curse, it does not reflect the total issuance cost borne by the Treasury Department, as our previous results suggest that the secondary market prices on auction days have already been driven down by these auctions.

To account for the price pressure effect resulting from Treasury auctions, we take as the benchmark price the average secondary Treasury market prices around each auction (rather than on the auction day). For example, for each n-year note auction, the benchmark is the average yield of the on-the-run (soon-to-become off-the-run) n-year note during the days around the auction (we track the same security throughout this window). We then calculate the amount of money the Treasury Department could have saved were it able to issue Treasury notes at this benchmark yield. This may be a conservative estimate since the auctioned security will become on-the-run in a few days and should be worth more than the soon-to-be-off-the-run security in the secondary market, as suggested by the well-known on-the-run-off-the-run phenomenon (e.g., Amihud and Mendelson (1991), Krishnamurthy (2002)).[9]

Table IV shows that Treasury issues notes at yields that are significantly higher than the benchmark yield in the secondary market. Panel A reports $Y(A) - \bar{Y}(t)$, where $Y(A)$ is the auction yield of the n-year note and $\bar{Y}(t)$ is the average of the on-the-run (soon-to-become off-the-run) n-year note yields on the t^{th} day before and t^{th} day after the auction, with t ranging from 1 to 10. For 2-year notes, this yield difference measure, $Y(A) - \bar{Y}(t)$, for $t = 1$, 5, and 10 is 3.63 ($t = 5.77$), 4.90 ($t = 4.62$), and 5.05 ($t = 3.42$) basis points, respectively. The results are similar for 5- and 10-year notes. For $t = 5$, for

[9] An alternative approach is to compare the auction yield with the traded yield (of the same security) immediately after issuance. This alternative estimate implies an even larger issuance cost.

instance, the yield difference is 4.04 (t = 4.70) basis points for 5-year notes and 2.66 (t = 3.12) basis points for 10-year notes.

Based on these yield differences, we further compute the implied cost borne by the Treasury Department both as a fraction of total issuance size and in dollar terms. As shown in columns 1, 3, and 5 in Panel B, based on the yield difference for $t = 5$, the issuance costs for 2-, 5-, and 10- year notes are 9.07, 16.81, and 18.43 basis points of the auction size, respectively. These estimates amount to substantial costs to the Treasury Department. Based on the total auction size of Treasury notes in 2007, the last full year in our sample, the implied total issuance cost is around $649 million.

We further decompose this cost measure, $Y(A) - \bar{Y}(t)$, into two components: $Y(A) - Y(0)$ and $Y(0) - \bar{Y}(t)$, where $Y(0)$ is the yield of the on-the-run n-year note on the auction day. The first component, $Y(A) - Y(0)$, is due to auction underpricing and the second component, $Y(0) - \bar{Y}(t)$, is due to the price impact shown in Tables II and III. This price-impact-induced issuance cost is reported in columns 2, 4, and 6 of Panel B in Table IV. For $t = 5$, for instance, the issuance costs that can be directly attributed to the price impact are 4.30, 11.09, and 14.19 basis points of the auction size for 2-, 5-, and 10- year notes, respectively. Hence, 50% to 80% of the total issuance cost can be attributed to the price impact effect. We note that the above decomposition is based on a crude measurement of auction underpricing. A better measure is perhaps the difference between the auction yield and the implied yield in the when-issued market at the time of the auction. Goldreich (2007), using data from the when-issued market, shows that the average auction underpricing is 0.32 basis points in yield in his 1992-

2000 sample. From this estimate of underpricing, we can attribute more than 90% of the issuance cost to the price pressure effect.

While it is by no means clear whether part of the above estimated issuance cost can be saved through better designs of the Treasury issuance mechanism, recognizing this cost is undoubtedly an essential first step to assess and improve the efficiency of the auction mechanism. For example, our evidence in the next section suggests that the issuance cost (as a fraction of the auction size) increases with the auction size. This implies that the Treasury can reduce its issuance cost by increasing auction frequency and reducing the size of each auction.

IV. Interpretations

It seems natural to try to link our results to the information revealed in Treasury auctions. Although the date and amount of each auction are announced in advance, auction outcomes, such as the bid-to-cover ratio, may contain information about the Treasury markets and overall economic conditions. If the uncertainty about auctions is resolved gradually during the days leading up to these auctions, we should expect that the average Treasury returns before auctions (including the auction day) be higher than those after. This prediction, however, is exactly the opposite of what we find in the data.

A more plausible interpretation is that Treasury auctions exert temporary price pressure in secondary Treasury markets. This interpretation has two ingredients. The first one is that primary dealers have limited risk-bearing capacity. In the U.S. Treasury market, primary dealers are expected to participate actively in all auctions and submit meaningful bids. [10] In other words, primary dealers are expected to acquire large positions in these auctions. Due to limited risk-bearing capacity, primary dealers hedge this to-be-acquired exposure by shorting similar securities in the secondary Treasury market as well as the when-issued market. These short-selling activities exert downward pressure on secondary market prices. Note that primary dealers' short selling in the when-issued market can also depress spot Treasury prices if the counterparties with long positions in the when-issued market hedge their exposures in the secondary Treasury market. Fleming and Rosenberg (2007) provide direct evidence that primary dealers reduce their positions shortly before Treasury auctions, similar to the inventory adjustment in the equity market documented in Hendershott and Seasholes (2007).

The second ingredient of our interpretation is that arbitrageurs and end-investors in the Treasury market are constrained from providing liquidity instantly. For one thing, arbitrageurs are unlikely to be able to absorb the entire supply from Treasury auctions, which is in the magnitude of tens of billions of dollars. In addition, major end-investors, including foreign investors, state and local governments, insurance companies, and bond mutual funds are passive investors, many of whom do not have the intention, or resources, to engage in short-term arbitrage trades. Our interpretation has a number of further implications, which we explore next.

A. Trading profits

The documented price pattern around Treasury auctions implies significant trading profits, at least before transaction costs. For example, to take advantage of the price

[10] According to *Administration of Relationships with Primary Dealers*, "Primary dealers are also required to participate in all auctions of U.S. government debt." http://www.ny.frb.org/markets/pridealers_policies.html.

movements around 2-year note auctions that take place almost every month in our sample, one can short the on-the-run 2-year note in the t days before each auction, and long a duration-matched portfolio comprising the on-the-run 6-month T-bill and 10-year note to hedge the interest rate risk. One can then switch to the reverse positions—i.e., long the 2-year note and short the 6-month bill and 10-year note—in the t days after the auction.

The trading profit from this strategy is reported in Table V. Panel A reports the results based on the full sample, without accounting for trading costs. The portfolio return is significant and positive for all t ranging from 1 to 10, with 9 out of the 10 return estimates being significant at the 1% level. For $t = 10$, for instance, the average return of this trading strategy is 8.62 basis points ($t = 3.65$) per month. For the more recent sample period (1998-2008), Panel B of Table V shows that our simple strategy yields similar returns: 8.52 basis points per month, with a t-statistic of 4.95.

Panel C of Table V reports the strategy returns after accounting for repo funding costs and bid-ask spreads. Specifically, we first subtract the daily return of each Treasury security involved in this trading strategy by 1/360 of the overnight special repo rate backed by the security. Due to the availability of the special repo rate data, Panel C focuses on the more recent sample of 1998-2008. In addition, we subtract from the cumulative long-short portfolio return the total bid-ask spread incurred in the trading strategy. Bid-ask spread estimates are obtained from Fleming (2003), who calculates daily interdealer bid-ask spreads for on-the-run Treasury securities using firm/market quotes from GovPX for the period of December 1996 to March 2000. He finds that the average bid-ask spreads for 10-year, 2-year, and 6-month Treasury securities are 2.44, 0.66, and 0.37 basis points, respectively. According to our duration estimates, the hedge portfolio has roughly 20% in 10-year notes and 80% in 6-month T-bills. Thus the bid-ask spread for the whole long-short portfolio is 0.66+2.44x0.2+0.37x0.8 = 1.46 basis points. Since our trading strategy involves two round trips each month, the total cost is 2.92 (= 1.46x2) basis points per month.

Panel C shows that repo funding costs and bid-ask spreads significantly reduce the profitability of the strategy. In particular, for $t \leq 6$, trading costs render the strategy unprofitable. For longer holding periods ($t \geq 7$), the strategy is still profitable, with an annualized Sharpe ratio of 0.84 for $t = 10$. This is comparable to the Sharpe ratios achieved by some well-known anomalies. For example, the Sharpe ratios of currency carry trades and stock price momentum are 0.59-0.95 and 0.47-0.75, respectively (see, e.g., Brunnermeir, Nagel, and Pedersen (2009), Lustig, Roussanov, and Verdelhan (2009) and Asness, Moskowitz, and Pedersen (2008)).

B. Limited risk-bearing capacity

The limited-risk-bearing-capacity interpretation implies that the price impact of Treasury auctions should be stronger when primary dealers find it more costly to bear risks; for instance, when Treasury interest rates are more volatile, when it is more costly for dealers to obtain leverage, or when the auction size is larger.

To test these predictions, we conduct a number of time-series regressions. The dependent variable is the cumulative return of the long-short portfolio defined in Table V during the 20-day window around an auction, which measures the price impact of the Treasury auction. The independent variables include the interest rate volatility and broker-dealers' leverage constraint before the auction. To capture interest rate uncertainty, we use Treasury-option-implied volatility, *Treasury IV*. Specifically, we use

Mueller, Vedolin, and Yen (2011)'s model-free estimates of maturity-weighted average implied volatilities of nearest-to-expiry at-the-money options on the 30-year, 10-year, and 5-year Treasury securities at the end of the previous month. To capture the broker-dealers' leverage constraint, we use the growth rate of the aggregate leverage for broker-dealers, *BD Lev Growth*, following the work by Adrian, Etula, and Muir (2012). We also include *VIX*, the implied volatility of S&P500 index options, in the regression, since it is often used as a proxy for the broker-dealers' funding constraint.

The results are summarized in Panel A of Table VI. Consistent with the prediction, we find that the price impact of Treasury auctions is more pronounced when interest rates are more volatile (i.e., *Treasury IV* is higher), when it is more costly for broker-dealers to obtain leverage (i.e., *BD Lev Growth* is lower), or when broker-dealers face tighter funding constraints (i.e., *VIX* is higher). In univariate regressions, the coefficient estimates on *Treasury IV*, *BD Lev Growth*, and *VIX* are -0.13 (t = -2.25), 0.39 (t = 1.85), and 1.26 (t = 2.83), respectively. In other words a one-standard-deviation increase in *Treasury IV*, *BD Lev Growth*, and *VIX* leads to a higher hedge-strategy return of 2.21 (= 1.26x1.75), 3.82 (= 0.13x29.36), and 3.21 (= 0.39x8.24) basis points, respectively. In the last column, where the regression specification includes all three variables, the coefficients on *Treasury IV* and *BD Lev Growth* remain statistically significant.

We next examine the effect of offering size on our documented price pressure effect. One natural test is to also include offering size in the regression shown in Panel A.[11] However, auctions of other maturities often occur in the vicinity of 2-year note

[11] In a univariate regression of hedge strategy returns on log(offering size) with year-fixed effects, the coefficient on log(offering size) is 4.58 (t=1.71).

auctions. For example, in a large portion of our sample, there is a 5-year note auction within a few days following each 2-year note auction. If there is a cross-maturity spillover effect (which we examine below), these 5-year note auctions could distort the price impact of 2-year note auctions. Hence, we adopt the following alternative methodology.

We construct a measure of "offering size imbalance," $OSI(n)$, which is defined as the logarithm of the aggregate offering amount from all Treasury note auctions of any maturity during the n days prior to the day in question (i.e., day 0) minus that during the n days following day 0. The idea is that if more Treasury securities will be auctioned in the next few days, the price pressure implies a low return today. On the other hand, if more securities were auctioned in the previous few days, the recovery from that price pressure implies a high return today. In other words, our price pressure interpretation implies a positive relation between bond return today and $OSI(n)$. To deal with time-variation in expected bond returns, we use the daily 2-year note return minus the average 2-year return in the surrounding 20 days as the dependent variable.[12] Consistent with our prediction, as shown in Panel B of Table VI, the coefficients estimates on $OSI(n)$ are significantly positive. For example, the coefficient is 0.029 ($t = 2.79$) for $OSI(5)$. That is, a \$20 billion auction (the average size of a 2-year note auction) in the past 5 days implies a 0.69 (= 0.029xlog(20 billion)) basis points higher 2-year bond return today. The second column shows the analysis based on $OSI(10)$. The result is similar to that in the first column, with a coefficient estimate of 0.046 ($t = 3.83$).

[12] We also use unadjusted daily returns as the dependent variable. The results are similar.

The limited risk-bearing capacity interpretation also implies a cross-maturity spillover effect, as formalized in the model with limited arbitrage by Vayanos and Vila (2009). Given the similarities among Treasury notes across maturities, to hedge for an incoming auction, primary dealers may short securities whose maturities are close to the auctioned maturity. Hence, the price pressure resulting from Treasury auctions of one maturity may spill over to other maturities, and this spillover effect should be stronger if the maturity differential is smaller.

To test these predictions, we examine the yield patterns of 10-year notes around 2- and 5-year note auctions. We exclude observations where there is a 10-year note auction within one week of a 2- or 5-year note auction, to ensure that we are not picking up the effect of own auctions.[13] Consistent with the prediction, Table VII shows that 10-year note yields increase before both 2- and 5-year note auctions and decrease afterward. Moreover, because of the large difference in maturities between 2- and 10-year notes, the magnitude of 2-year note auctions' spillover effect on 10-year yields is small, hovering around one basis point. In contrast, 5-year note auctions have a much stronger spillover effect on 10-year yields. The impact is around 3 basis points, and is highly statistically significant.

In sum, the evidence here lends further support to our hypothesis that, due to limited risk-bearing capacity, primary dealers hedge the risk they are expected to acquire at auctions by short selling similar securities, thus exerting downward price pressure in the secondary markets before these auctions. We find that the price impact

[13] This requirement significantly limits our potential choices. For example, it is difficult to examine the yield patterns of 2-year notes around auctions of 5- or 10-year notes, as there are only a small number of 5- and 10-year note auctions that are not within one week of any 2-year note auction.

is more pronounced when interest rates are more volatile, when broker-dealers are more capital constrained, or when the offering size is larger.

C. End-investors' capital mobility

The second ingredient in our interpretation is that end investors in the Treasury market are unresponsive to transitory yield changes. Major investors in Treasury markets are indeed likely to be passive. According to data from the Treasury Department, the total size of the "private holdings" of Treasury securities is around $5 trillion in 2008, of which foreign investors and state and local governments account for more than half. [14] While there are no high-frequency detailed data on these investors' trading, it seems reasonable to expect that many of them do not have the intention, or resources, to engage in short-term arbitrage trades.

Bond mutual funds collectively hold close to 500 billion dollars' worth of Treasury securities in 2008, which accounts for around 10% of all private holdings. Index bond mutual funds are likely to avoid newly issued securities due to concerns of tracking errors. Since many fixed-income indices adjust their compositions at the end of each month, index bond mutual funds are usually reluctant to purchase the new securities before they are included in the indices they are tracking. [15] In other words, rather than exploiting the yield changes around auctions, index funds might be part of the cause of the phenomenon.

[14] The data on the ownership of Treasury securities are from http://fms.treas.gov/bulletin/index.html.

[15] For example, Barclays US Treasury Bond Index adjusts its composition on the last calendar day of each month; see, https://ecommerce.barcap.com/indices.

Insurance companies collectively hold about \$160 billion of Treasury securities at the end of our sample, which amounts to 3% of the private holdings. According to the trading records of insurance companies' annual reports to National Association of Insurance Commissioners, insurance companies trade very infrequently in the Treasury market. For example, close to 70% of all insurance companies make less than five trades and around 14% of them do not make any trade in any given year. While this finding is consistent with insurance companies' general objective to maintain a low turnover, it suggests that insurance companies are unlikely to absorb sudden supply changes in the Treasury market over the course of few days.

D. The Impact on Interest Rates

Our limited risk-bearing capacity interpretation also implies that primary dealers' shorting activities before Treasury auctions can impact repo (repurchase agreement) rates. In order to take short positions, primary dealers usually borrow Treasury securities through reverse repo transactions (from the perspective of their counterparties, these are repo transactions). That is, primary dealers lend cash to their counterparties and take Treasury securities as collateral, which they then sell short in the secondary market. Naturally, primary dealers have strong incentives to initiate these reverse-repo transactions shortly before Treasury auctions than in other periods. As a result, they would be willing to accept lower interest rates in these transactions, leading to lower special repo rates before auctions.

To test this idea, we compare the average repo rate backed by the n-year note before an n-year note auction with that after the auction, for n = 2, 5, and 10. The results are reported in Panel A of Table VIII. Consistent with the prediction, the special repo rates in the pre-auction period are significantly lower than those in the post-auction period. For example, as shown in column 1, the average overnight special repo rate backed by on-the-run 2-year notes during the 10 days before 2-year note auctions is, on average, 15.11 basis points lower than that during the 10-day period after these auctions, with a t-statistic of 4.13. This rate differential is highly significant for all but the first two days, and reaches its maximum on day 5, with a point estimate of 24.95 basis points and a t-statistic of 5.47. There is a similar pattern for the overnight special repo rates backed by 5- and 10-year notes around 5- and 10-year note auctions, respectively. For 5-year notes, for example, the average 5-day pre-auction special repo rate is 22.59 basis points (t = 3.21) lower than that during the post-auction 5-day period. For 10-year notes, this special repo rate differential is 31.94 basis points (t = 1.87). We note that there is a standard liquidity interpretation of the specialness. Prior to an auction, the existing on-the-run security trades on special because of its superior liquidity. Although we provide an alternative arbitrageur interpretation here, it is related to the liquidity interpretation as well: One of the reasons that dealers establish short positions in on-the-run securities is perhaps their superior liquidity.

Since different types of interest rates are tied closely together, we expect to see a spillover effect from special repo rates to other types of interest rates. Moreover, on issuance days (usually a couple of business days after auction days), dealers need to purchase the securities they acquire at auctions, which is usually financed through repo transactions. Given the size of these Treasury auctions (in the order of tens of billions of dollars in a few days), it is conceivable that this borrowing demand can also push up interest rates after auctions.

To test this prediction, we extend our analyses to general-collateral (GC) repo rates, Fed Funds rates, Libor rates, and AA-rated non-financial commercial paper rates. Since many of these series are available only for a subperiod of our sample, we center our analysis on the most frequent 2-year note auctions to increase statistical power. As shown in Panel B of Table VIII, interest rates are generally lower in the few days before, and are higher in the few days after auctions. The magnitude of these interest rate differentials is much smaller compared to that observed for special repo rates. For example, the average rate differential between the 5-day pre-auction period and 5-day post-auction period is 6.75 (t = 4.83), 3.80 (t = 3.32), 5.03 (t = 4.74), and 7.11 (t = 4.15) basis points for the GC repo rate, Fed Funds rate, Libor rate, and AA-rated nonfinancial commercial paper rate, respectively. Our findings complement those in Keane (1996), who focuses on the specialness component of overnight repo rates. Our results further suggest that Treasury auctions also affect the GC component of repo rates, as well as Fed Funds rates, Libor rates, and commercial paper rates.

V. Robustness

The price impact pattern discussed in this paper is not unique to on-the-run securities. We repeat the analysis in Table II for off-the-run Treasury securities. As can be seen in the bottom row of Figure 1, the yield pattern for off-the-run notes is very similar to that for on-the-run securities (detailed results are omitted for brevity).

One potential concern with our documented yield pattern is that bond yields have decreased dramatically during our sample period. For example, two year note yields have decreased from well above 10% in the 1980s to around 2% at the end of our sample. To see if this decreasing trend in yields is driving our results, we repeat our analysis for various subsamples. For instance, during the second half of our sample (1995-2008), where there is no obvious trend in bond yields, we find similar (in fact slightly stronger) results for this subsample, suggesting that this trend in yields is not the driver of our results. Another potential concern is that many 2-year auctions are conducted at the end of a month, which may be confounded by the turn-of-month effect in bond returns. To see if these month-end auctions are driving our results, we repeat our analysis after excluding all auctions that are during the first n days or the last n days of each month (where n = 1, 2, ..., 5). Our coefficient estimates remain similar, albeit with lower statistical significance due to a reduced sample size, suggesting that the main results in the whole sample are not driven by month-end effects.

Finally, since Treasury auctions take place in the middle of a day, it is unclear whether the return on the auction day itself should be classified as pre-auction or post-auction. We repeat our analysis by excluding auction day returns and the results are by and large unchanged. Finally, since Treasury securities accumulate interest payments on each calendar day (rather than on each trading day), we accordingly adjust for the effect of weekends and holidays on our return patterns. The results are virtually identical to those discussed above.

VI. Conclusion

Despite being anticipated and frequently repeated, Treasury auctions have a significant price impact on the secondary Treasury and repo markets. We find that Treasury security prices in the secondary market decrease significantly in the few days leading up to Treasury auctions and recover shortly thereafter. The price pressure effects we document here are economically important. The implied issuance costs borne by the

Treasury Department are an order of magnitude larger than the estimates in the extant auction underpricing literature. Our evidence suggests that the Treasury can potentially reduce the issuance cost by increasing the auction frequency and reducing the size of each auction. We further attribute these results to the limited risk-bearing capacity of primary dealers and the imperfect capital mobility of some classes of investors. Our results thus suggest that market frictions play an important role even in the most liquid and well-developed financial markets.

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Table I: Summary Statistics

Panel A reports the summary statistics of Treasury note auctions. *Maturity* is the number of years to maturity of a Treasury note. Under *Auction Type*, "Multiple" denotes a multiple-price auction and "Single" denotes a single-price auction. *No. of Issues* is the total number of issues in our sample. *Amount* is the face value issued at each auction. *Bid-to-Cover Ratio* is the ratio of total face value bid in an auction to the total face value issued to all competitive bidders. *Auction Yield* is the maximum winning yield for a single-price auction, and is the weighted-average yield based on the amount issued at each winning yield for a multiple-price auction. Panel B reports the summary statistics for Treasury notes. *Daily Treasury note return* is the daily return, including coupon distributions. *Treasury note duration* is the modified duration (expressed in years) of the on-the-run security on the auction day. Panel C reports the summary statistics for other data. *Treasury IV* is the model-free maturity-weighted implied volatility of nearest-to-expiry at-the-money Treasury options on the 30-year, 10-year, and 5-year Treasury securities. *VIX* is the implied volatility from S&P 500 index options. *BD Lev Growth* is the aggregate leverage growth of broker-dealers. *Overnight Special Repo Rate* is the overnight special repo rate backed by specific on-the-run Treasury securities. *Overnight GC* is the overnight general collateral repo rate. *Fed Funds Rate* is the overnight federal funds rate. *Overnight Libor* is the overnight US dollar Libor rate. *Overnight CP* is the AA-rated nonfinancial overnight commercial paper rate. Yields and interest rates are expressed in percentages, and daily returns are expressed in basis points. The sample period for Panels A and B is January 1980 to June 2008. The starting year of each data series in Panel C is indicated in parenthesis and all series end in June 2008.

Panel A: Summary statistics of Treasury auctions (1980-2008)

Maturity	Auction Type	No. of Issues	Amount ($ Billions) Mean	Amount ($ Billions) Stdev	Bid-to-Cover Ratio Mean	Bid-to-Cover Ratio Stdev	Auction Yield (%) Mean	Auction Yield (%) Stdev
2	Multiple	150	10.13	3.24	2.68	0.56	9.26	2.59
2	Single	182	22.93	6.21	2.61	0.4	5.09	1.28
2	Total	332	17.13	8.16	2.64	0.48	6.36	2.62
5	Multiple	64	7.66	2.41	2.78	0.49	8.78	2.61
5	Single	146	14.83	2.84	2.57	0.38	4.68	0.66
5	Total	210	12.64	4.27	2.63	0.43	7.01	2.86
10	Multiple	75	9.92	3.65	2.44	0.34	7.76	3.19
10	Single	57	13.03	4.01	2.38	0.43	5.29	0.64
10	Total	132	11.27	4.1	2.41	0.38	7.57	3.14

Panel B: Summary statistics of Treasury notes (1980-2008)					
Variables	Mean	Standard Deviation	25th	Median	75th
Daily Treasury note returns (basis point)					
2-Year Note	2.85	16.24	-4.24	2.34	9.63
5-Year Note	3.33	34.48	-13.65	3.08	20.58
10-Year Note	3.36	49.75	-23.16	3.33	30.45
Treasury note durations (year)					
2-Year Note	1.78	0.07	1.74	1.79	1.83
5-Year Note	4.16	0.27	4.04	4.19	4.34
10-Year Note	6.98	0.88	6.40	7.07	7.74

Panel C: Other data (starting years vary)					
Proxies of Primary Dealers' Risk Capacity (%)					
Treasury IV(1980-)	8.00	1.75	6.99	7.75	8.82
VIX (1990-)	20.39	8.24	14.45	19.02	24.02
BD Lev Growth (1986-)	10.68	29.36	-4.97	13.19	29.09
Overnight Special Repo Rates (%)					
6-Month Bill (1996-)	2.88	2.17	0.45	2.45	5.15
2-Year Note (1996-)	2.65	2.20	0.29	2.05	5.10
5-Year Note (1996-)	2.49	2.19	0.25	2.00	4.85
10-Year Note (1996-)	2.29	2.12	0.22	1.65	4.55
Other Interest Rates (%)					
Overnight GC (1991-)	3.97	1.63	2.90	4.49	5.31
Fed Funds Rate (1982-)	5.42	2.49	3.59	5.38	6.97
Overnight Libor (2001-)	3.10	1.63	1.73	2.80	4.80
Overnight CP (1998-)	3.73	1.82	1.78	4.32	5.26

Table II: On-the-Run Treasury Yields around Auctions

This table reports the time-series average of $Y(t) - Y(0)$, where $Y(t)$ is the yield of an on-the-run n-year Treasury note (n=2, 5, 10) on day t, with t ranging from -10 to 10, $Y(0)$ is the yield of the same note on the day when an n-year note auction is conducted. (The note is on-the-run before the auction and becomes off-the-run after the auction.) The sample period is from January 1980 to June 2008. All yields are expressed in basis points. T-statistics are based on standard errors that are Newey-West (1987) adjusted with 12 lags, and are reported in parentheses. ***, **, and * indicate significance levels of 1%, 5%, and 10%, respectively.

On-the-run Treasury yields around auctions: $Y(t) - Y(0)$						
	2-year notes		5-year notes		10-year notes	
t	Mean	t-stat	Mean	t-stat	Mean	t-stat
-10	-1.16	(-0.59)	-2.68*	(-1.87)	-0.79	(-0.39)
-9	-1.82	(-0.98)	-2.50	(-1.60)	-2.14	(-1.21)
-8	-2.86	(-1.50)	-3.35**	(-2.43)	-1.64	(-0.95)
-7	-3.04*	(-1.68)	-2.61*	(-1.95)	-0.10	(-0.06)
-6	-2.64*	(-1.83)	-2.07	(-1.54)	-1.03	(-0.71)
-5	-2.53	(-1.50)	-2.67**	(-2.50)	-1.57	(-1.11)
-4	-2.81*	(-1.77)	-2.96***	(-3.08)	-2.76**	(-2.02)
-3	-3.01**	(-2.21)	-1.56*	(-1.80)	-2.25**	(-2.04)
-2	-2.06**	(-2.03)	-0.64	(-1.14)	-0.41	(-0.52)
-1	-1.77***	(-3.18)	0.30	(0.67)	-0.78	(-1.20)
1	-0.36	(-1.11)	-0.77**	(-2.02)	-0.56	(-1.21)
2	-0.67	(-1.09)	-1.74***	(-2.88)	-1.23	(-1.40)
3	-0.87	(-0.97)	-2.46***	(-2.97)	-1.87*	(-1.70)
4	-1.92*	(-1.94)	-1.96**	(-2.37)	-2.01	(-1.62)
5	-2.32**	(-2.18)	-2.74***	(-2.63)	-2.00	(-1.51)
6	-3.19**	(-2.61)	-2.11	(-1.58)	-1.48	(-1.32)
7	-2.93**	(-2.14)	-2.75	(-1.58)	-2.78*	(-1.70)
8	-2.77	(-1.60)	-3.41**	(-2.10)	-3.42*	(-1.90)
9	-3.19*	(-1.74)	-3.09*	(-1.95)	-4.47**	(-2.07)
10	-3.91**	(-2.13)	-2.95*	(-1.88)	-4.68**	(-2.00)
No. Obs.	332		210		132	

Table III: On-the-Run Treasury Returns around Auctions

This table reports the time-series average of $\Delta CR(t)$, which is the cumulative return of an n-year Treasury note (n=2, 5, 10) during the t days after an n-year note auction minus the cumulative return of the same n-year note during the t days before the auction, where t ranges from 1 to 10. (The note is on-the-run before the auction and becomes off-the-run after the auction.) Panel A reports the results for the entire sample from January 1980 to June 2008. Panel B reports Treasury returns net of the repo financing costs for the period of January 1998 to June 2008 (due to the availability of repo data). All returns are expressed in basis points. T-statistics are based on standard errors that are Newey-West (1987) adjusted with 12 lags, and are reported in parentheses. ***, **, and * indicate significance levels of 1%, 5%, and 10%, respectively.

Panel A: Treasury note returns around auctions: $\Delta CR(t)$

	2-year notes		5-year notes		10-year notes	
t	Mean	t-stat	Mean	t-stat	Mean	t-stat
1	3.68***	(3.90)	1.98	(0.99)	8.61	(1.53)
2	3.54**	(2.21)	9.94***	(4.03)	10.87	(1.13)
3	6.15**	(2.42)	16.86***	(4.28)	26.37**	(2.31)
4	8.66***	(2.87)	20.86***	(4.34)	31.61***	(2.75)
5	8.89***	(2.69)	22.54***	(3.67)	23.84*	(1.78)
6	10.20***	(3.62)	17.12**	(2.07)	16.44	(1.31)
7	9.42***	(2.63)	21.21**	(2.20)	17.44	(1.01)
8	9.61**	(2.28)	27.59***	(3.01)	30.4*	(1.67)
9	9.08**	(2.23)	22.85**	(2.43)	40.68**	(2.02)
10	9.20**	(2.02)	22.77**	(2.53)	32.45	(1.39)
No. Obs.	332		210		132	

Panel B: Treasury note returns (net of repo costs) around auctions						
	2-year notes		5-year notes		10-year notes	
t	Mean	t-stat	Mean	t-stat	Mean	t-stat
1	3.06***	(3.16)	1.04	(0.31)	5.32	(0.73)
2	4.35***	(3.26)	9.04**	(2.38)	4.16	(0.35)
3	4.86**	(2.33)	11.53**	(2.50)	17.49	(1.60)
4	8.76***	(3.82)	15.07***	(2.88)	24.69*	(1.66)
5	9.53***	(4.70)	15.99**	(2.31)	12.44	(0.87)
6	11.25***	(4.42)	6.82	(0.67)	12.39	(0.92)
7	10.02***	(3.32)	9.20	(1.09)	4.88	(0.27)
8	11.17***	(2.96)	13.05*	(1.65)	17.36	(1.39)
9	9.88***	(2.76)	9.23	(1.07)	26.22*	(1.91)
10	11.50***	(2.80)	8.32	(1.03)	9.64	(0.53)
No. Obs.	137		98		68	

Table IV: Implied Issuance Costs of Treasury Notes

Panel A of this table presents the time-series average of $Y(A) - \bar{Y}(t)$, where $Y(A)$ is the auction yield of the newly auctioned Treasury note, and $\bar{Y}(t)$ is the average of the yield of the on-the-run n-year note (n=2, 5, 10) on day t before the auction and the yield of the same note on day t after the auction, with t ranging from 1 to 10. (The note is on-the-run before the auction and becomes off-the-run after the auction.) The auction yield is the maximum winning yield for single-price auctions, and is the weighted-average yield based on the amount issued at each winning yield for multiple-price auctions. The sample period is from January 1980 to June 2008. Yields are expressed in basis points. Panel B of this table presents the estimated cost of issuing Treasury notes. The total issuance cost (column Total) is calculated as the product of $Y(A) - \bar{Y}(t)$ and the duration of the notes, and is expressed in basis points. The issuance cost due to price impact (column Price Impact) is calculated as the product of $Y(0) - \bar{Y}(t)$ and the duration of the notes, and is expressed in basis points, where $Y(0)$ is the yield of the on-the-run n-year note on the auction day. The second last column, Total Amount, reports the estimated total dollar amount cost for issuing all notes in 2007. The last column, Price Impact, reports the total issuance cost that is attributable to price impact. T-statistics are based on standard errors that are Newey-West (1987) adjusted with 12 lags, are reported in parentheses. ***, **, and * indicate significance levels of 1%, 5%, and 10%, respectively.

Panel A: Yield difference $Y(A) - \bar{Y}(t)$						
	2-year notes		5-year notes		10-year notes	
t	Mean	t-stat	Mean	t-stat	Mean	t-stat
1	3.63***	(5.77)	1.58**	(2.63)	1.36*	(1.84)
2	3.90***	(5.40)	2.52***	(3.65)	1.52	(1.58)
3	4.50***	(5.07)	3.42***	(4.36)	2.84**	(2.26)
4	4.84***	(4.88)	3.86***	(4.52)	3.19***	(3.13)
5	4.90***	(4.62)	4.04***	(4.70)	2.66***	(3.12)
6	5.33***	(5.98)	3.44***	(3.34)	2.21**	(2.34)
7	5.42***	(5.17)	3.95***	(3.01)	2.43*	(1.65)
8	5.38***	(4.18)	4.69***	(3.82)	3.59*	(1.90)
9	5.03***	(3.82)	4.06***	(3.41)	4.39**	(2.07)
10	5.05***	(3.42)	4.05***	(3.59)	3.85*	(1.71)
No. Obs.	332		210		132	

Panel B: Costs of issuance based on the average yield on days -t and t								
	2-year notes		5-year notes		10-year notes		All notes	
t	Total	Price Impact	Total	Price Impact	Total	Price Impact	Total Amount	Price Impact
1	6.72	1.95	6.57	0.87	9.42	5.16	\$354M	\$107M
2	7.22	2.46	10.48	4.77	10.53	6.24	\$437M	\$190M
3	8.33	3.57	14.23	8.53	19.68	15.40	\$600M	\$354M
4	8.95	4.21	16.06	10.35	22.11	17.83	\$665M	\$419M
5	9.07	4.30	16.81	11.09	18.43	14.19	\$649M	\$402M
6	9.86	5.11	14.31	8.60	15.32	11.06	\$604M	\$358M
7	10.03	5.28	16.43	10.73	16.84	12.56	\$654M	\$408M
8	9.95	5.19	19.51	13.77	24.88	20.58	\$768M	\$521M
9	9.31	4.55	16.89	11.18	30.42	26.18	\$757M	\$511M
10	9.34	4.59	16.85	11.13	26.68	22.40	\$726M	\$479M

Table V: Hedge Portfolio Returns

This table reports $HRet(t)$, the cumulative return of a hedge strategy from t days before an auction to t days after, where t ranges from 1 to 10. On the t^{th} day before each auction, we go short in the on-the-run 2-year note, and go long in a duration-matched portfolio of the on-the-run 6-month T-bill and 10-year note. We hold this portfolio until the auction day, and then reverse our positions: We now go long in the same 2-year note and go short in the duration-matched portfolio of the on-the-run 6-month T-bill and on-the-run 10-year note. We hold this portfolio until the t^{th} day after the auction. Panel A reports the results for the full sample, January 1980 to June 2008, Panel B for the subsample 1998-2008, and Panel C adjusts the hedge portfolio returns by bid-ask spreads and funding costs (i.e., we subtract the daily returns of each Treasury security involved in this trading strategy by 1/360 of the overnight special repo rate backed by the security). The mean returns are monthly and expressed in basis points. Sharpe Ratio is the annualized Sharpe ratio for this trading strategy. T-statistics are based on standard errors that are Newey-West (1987) adjusted with 12 lags, and are reported in parentheses. ***, **, and * indicate significance levels of 1%, 5%, and 10%, respectively.

	Panel A (1980-2008)			Panel B (1998-2008)			Panel C (1998-2008) adjust for funding costs and bid-ask spreads		
t	Mean	t-stat	Sharpe Ratio	Mean	t-stat	Sharpe Ratio	Mean	t-stat	Sharpe Ratio
1	1.04*	(1.67)	0.34	-0.40	(-0.47)	-0.14	-3.32***	(-3.40)	-1.08
2	2.40***	(2.89)	0.66	1.37	(1.60)	0.50	-1.68**	(-2.06)	-0.66
3	4.41***	(3.35)	0.94	2.61***	(2.68)	0.84	-0.53	(-0.57)	-0.18
4	4.96***	(3.30)	0.98	4.15***	(4.01)	1.05	0.27	(0.23)	0.07
5	5.87***	(3.10)	0.95	4.78***	(3.48)	1.06	0.82	(0.54)	0.17
6	6.39***	(3.95)	1.05	6.85***	(4.66)	1.32	2.64	(1.59)	0.51
7	8.17***	(4.00)	1.2	8.02***	(5.14)	1.56	4.24**	(2.26)	0.73
8	8.10***	(3.88	1.12	7.62***	(4.64)	1.41	4.38**	(2.36)	0.76
9	8.24***	(3.60)	1.08	8.13***	(5.08)	1.44	4.29**	(2.53)	0.82
10	8.62***	(3.65)	1.08	8.52***	(4.95)	1.44	4.66***	(2.62)	0.84
No. Obs.		319			116			116	

Table VI: Dealers' Risk-Bearing Capacity

This table presents the effect of primary dealers' risk-bearing capacity and auction size on Treasury security returns around auctions. The dependent variable in Panel A, $HRet(10)$, is the hedge portfolio return surrounding a 2-year note auction as described in Table V and is expressed in basis points. *Treasury IV* is the model-free maturity-weighted implied volatility of nearest-to-expiry at-the-money Treasury options at the end of the previous month. *BD Lev Growth* is the aggregate leverage growth of broker-dealers in the previous quarter. *VIX* is the implied volatility of S&P 500 index options in the previous month. We ensure that all the independent variables are measured before the auction takes place. The dependent variable in Panel B is the daily return of on-the-run 2-year Treasury notes in basis points, adjusted by the average daily return in the 20-day windows surrounding it. $OSI(n)$ is the logarithm of the aggregate offering amount from all Treasury note auctions of any maturity type during the *n* days prior to the return date minus that during the *n* days after the return date. The sample period is January 1990 to June 2008 for Panel A (due to the availability of the VIX index) and is January 1980 to June 2008 for Panel B. T-statistics are based on standard errors that are Newey-West (1987) adjusted with 12 lags, and are reported in parentheses. ***, **, and * indicate significance levels of 1%, 5%, and 10%, respectively.

Panel A: Dependent Variable = $HRet(10)$				
	[1]	[2]	[3]	[4]
Treasury IV	1.26***			1.08**
	(2.83)			(2.29)
BD Lev Growth		-0.13**		-0.10*
		(-2.25)		(-1.77)
VIX			0.39*	0.16
			(1.85)	(1.12)
Adjusted R^2	0.034	0.024	0.013	0.050
No. Obs.	213	213	213	213

Panel B: Dependent Variable = daily 2-year note return		
	[1]	[2]
$OSI(5)$	0.029***	
	(2.79)	
$OSI(10)$		0.046***
		(3.83)
Adjusted R^2	0.001	0.002
No. Obs.	6,960	6,960

Table VII: On-the-Run 10-Year Treasury Yields around 2- and 5-Year Auctions

This table reports the time-series average of $Y(t) - Y(0)$, where $Y(t)$ is the yield of an on-the-run 10-year Treasury note on day t (where t ranges from -5 to 5), $Y(0)$ is the yield of the same note on the day when an n-year (n=2, 5) note auction is conducted. We exclude 2- and 5- year note auctions that are within one week of any 10-year note auction. The sample period is from January 1980 to June 2008. All yields are expressed in basis points. T-statistics are based on standard errors that are Newey-West (1987) adjusted with 12 lags, and are reported in parentheses. ***, **, and * indicate significance levels of 1%, 5%, and 10%, respectively.

10-year Treasury yields around 2- and 5-year note auctions: $Y(t) - Y(0)$				
	around 2-year note auctions		around 5-year note auctions	
t	Mean	t-stat	Mean	t-stat
-5	-1.48	(-1.50)	-2.71**	(-2.26)
-4	-1.44	(-1.61)	-2.89**	(-2.51)
-3	-1.41*	(-1.72)	-1.57	(-1.60)
-2	-0.96	(-1.63)	-0.69	(-1.00)
-1	-1.20***	(-2.70)	0.01	(0.01)
1	-0.74*	(-1.93)	-0.22	(-0.42)
2	-0.44	(-0.67)	-2.12***	(-2.98)
3	0.23	(0.22)	-3.08***	(-4.18)
4	-0.68	(-0.60)	-2.31***	(-2.90)
5	-0.8	(-0.61)	-3.22***	(-3.00)
No. Obs.	275		144	

Table VIII: Interest Rates around Treasury Auctions

This table reports the time-series average of $\Delta Rate(t)$, the average interest rates during the t days after a Treasury note auction minus that during the t days prior to the auction, where t ranges from 1 to 10. Panel A reports the results for special repo rates backed by n-year Treasury notes around n-year note auctions, for n=2, 5, 10. Panel B reports results for overnight general collateral repo rates (Overnight GC), overnight Fed Funds rates, overnight Libor rates, and AA-rated nonfinancial overnight commercial paper rate (Overnight CP) around 2-year note auctions. All interest rates are expressed in basis points. The sample period for Panel A is from January 1980 to June 2008. For Panel B, the sample starts in January 1991 for Overnight GC, January 1982 for Fed Funds rate, January 2001 for Overnight Libor, and January 1998 for Overnight CP, and all samples end in June 2008. T-statistics are based on standard errors that are Newey-West (1987) adjusted with 12 lags, and are reported in parentheses. ***, **, and * indicate significance levels of 1%, 5%, and 10%, respectively.

Panel A: Special Repo Rates around Treasury Auctions						
	2-Year Note		5-Year Note		10-Year Note	
t	Mean	t-stat	Mean	t-stat	Mean	t-stat
1	-6.76	(-0.74)	1.80	(0.51)	-4.38	(-0.31)
2	5.45	(0.90)	1.60	(0.35)	13.00	(1.17)
3	16.92***	(3.35)	10.20*	(1.93)	19.85*	(1.70)
4	24.66***	(5.38)	18.95***	(2.81)	26.64*	(1.87)
5	24.95***	(5.47)	22.59***	(3.21)	31.94*	(1.87)
6	23.29***	(5.70)	25.25***	(3.46)	36.47*	(1.87)
7	21.45***	(5.30)	25.91***	(3.77)	40.29*	(1.83)
8	18.20***	(4.75)	26.75***	(3.57)	41.05*	(1.77)
9	16.54***	(4.61)	27.07***	(3.30)	41.77*	(1.78)
10	15.11***	(4.13)	28.03***	(3.25)	42.62*	(1.78)
No. Obs.	123		92		66	

Panel B: Other Interest Rates around 2-Year Note Auctions								
	Overnight GC		Fed Funds Rate		Overnight Libor		Overnight CP	
t	Mean	t-stat	Mean	t-stat	Mean	t-stat	Mean	t-stat
1	1.38	(0.99)	6.73***	(4.41)	3.24***	(4.04)	3.54***	(4.68)
2	3.69**	(2.39)	4.88***	(3.94)	5.38***	(5.77)	5.94***	(4.83)
3	5.09***	(3.29)	5.71***	(5.23)	6.23***	(6.96)	8.47***	(4.55)
4	6.53***	(4.53)	4.78***	(4.23)	5.75***	(5.96)	8.03***	(4.55)
5	6.75***	(4.83)	3.80***	(3.32)	5.03***	(4.74)	7.11***	(4.15)
6	6.50***	(4.67)	3.61***	(3.33)	3.47***	(3.07)	5.43***	(3.21)
7	5.85***	(4.26)	3.52***	(3.38)	1.99**	(1.60)	3.41*	(1.88)
8	4.85***	(3.49)	3.73***	(3.20)	1.25	(0.91)	2.45	(1.16)
9	4.13***	(2.79)	3.55***	(2.64)	0.49	(0.33)	1.47	(0.64)
10	3.47**	(2.21)	3.14**	(2.38)	-0.15	(-0.09)	0.86	(0.35)
No. Obs.	198		298		87		120	

Figure 1: Treasury Yields around Auctions

Solid lines in these figures correspond to the time-series average of $Y(t) - Y(0)$, where $Y(t)$ is the yield of an n-year Treasury note (n=2,5,10) on day t (where t ranges from -5 to 5), $Y(0)$ is the yield of the same note on the day when an n-year note auction is conducted. The top three figures are for on-the-run Treasury notes (the notes are on-the-run before the auctions and become off-the-run after the auctions). The bottom three figures are for the first off-the-run notes (the notes are first-off-the-run before the auctions and become second-off-the-run after the auctions). The dotted lines are the 95% confidence interval. The sample period is from January 1980 to June 2008. All yields are expressed in basis points.