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Abstract

This study empirically analyzes the demand for Treasury securities at auctions over the period October 1998 through July 2010 from the perspective of bid composition and the influence of demand at auction in the secondary market. The results show that the demand at auction, measured by bid dispersion, is positively related to bid-to-cover ratio but negatively associated with the percentage of accepted competitive bids as well as the percentage of noncompetitive bids. Post-auction returns are positively related to demand at auction. The findings suggest the existence of arbitrage opportunities resulting from the price discrepancy between the auction and the secondary market when the demand for Treasuries is high.

Introduction

Since October 1998, the US Treasury has switched to uniform price auctions in order to more efficiently market new Treasury security issues. Under this system, all securities are awarded at the market clearing price. Prior to the implementation of this uniform price auction system, the Treasury adopted multiple price-discriminatory auctions, in which bidders would pay the price they bid and the reported yield was the weighted average of all accepted yields. Under this prior pricing mechanism, the "winners' curse" could (easily) occur, in that successful bidders needed to pay the actual price at bid, which could very well be higher than the market consensus. Presumably, with the current uniform price system, the fear of the "winner's curse" can be substantially reduced, leading to more aggressive bidding (Malvey and Archibald, 1998; Chatterjea and Jarrow,1998; Cammack, 1991).

Rising confidence among investors would likely increase the demand for Treasury securities and subsequently eventually affect the secondary market for those Treasury issues. Two issues arise. First, how might biddings at auction reflect demand for Treasury securities? Second, how might demand at auction influence the secondary market? We investigate these issues in the present study. A sound understanding of these issues can potentially not only help investors to establish proper trading strategies but also help policy makers to better understand the auction mechanism. The published research related to these topics still limited since existing studies mainly focus on the effectiveness of the uniform price system from the perspective of market efficiency and the revenues generated for the Treasury (Bikhchandani et al., 2000; Chatterjea and Jarrow, 1998; Godbout et al., 2002; Goldreich, 2007; Malvey and Archibald, 1998).

From Treasury Direct, a proprietary Treasury book entry system introduced in 1986 for the purpose of accommodating those retail investors that typically purchase securities in the primary market and hold them until maturity, we collected relevant auction data, such as aggregated tendered bid, the accepted yields, the clearing yield and price, and so forth. We find evidence that bidders prefer submitting competitive bids with lower yields over submitting noncompetitive bids because such a strategy helps to increase the likelihood of success in obtaining Treasury securities. The demand at auction decreases with the percentage of accepted competitive bids out of total competitive bids ("competitive acceptance ratio", hereafter) as well as the percentage of noncompetitive bids out of total tendered bids except those in FIMA account ("noncompetitive total ratio", hereafter). However, the demand at auction increases with the ratio of total accepted bids out of total tendered bids ("bid-to-cover ratio", hereafter). Those ratios can be used to proxy for demand at auction. We also find that the post-auction rate of return increases with demand at auction. Such findings suggest of price discrepancy between the auction and the secondary markets and thus imply the existence of arbitrage opportunities.

The remainder of the study is organized as follows: first, the analysis reviews the literature; next, it analyzes the relation between demand at auction and the various types of bids; subsequently, the study discusses the association between the post-auction return and demand at auction; and the final section provides the overall summary and conclusions.

Literature Review

The uniform price format replaced the multiple price-discriminatory system beginning with the October 1998 Treasury securities auction. Theoretically, such a price-format change can lead to more aggressive bidding in that fear of the winner's curse is reduced under the uniform pricing system. Moreover, more bidders would presumably participate due to the simpler bidding procedure under the uniform price auction (Nyborg and Strebulaev, 2004; Nyborg and Sundaresan, 1995; Malvey and Archibald, 1998). Chatterjea and Jarrow (1998) introduce a game theoretic equilibrium model for the U.S. Treasury securities auctions. They demonstrate that with uniform price format, the prisoner's dilemma encourages aggressive bidding, resulting in alleviation of the winners' curse. Sundaresan (2009) finds that the uniform price auction system has higher bid cover ratio and a higher dispersion of winning bids, implying increased revenues for the Treasury and a lowering of the cost of public debt issuance.

With the uniform price system, competitive bids are accepted in order of increasing yields until the offering amount is fully covered. Further, all successful bidders pay the same price, which is computed from the highest accepted yield. Although anyone may submit competitive bids, the competitive bidding is dominated by the primary dealers. By contrast, noncompetitive bidders are mainly individual investors. They submit sealed bids specifying quantity only and always win at a discount rate equal to the high yield of the competitive bids (Bikhchandani et al., 2000).

Although competitive bidders just need to specify a minimum yield at which the participant is willing to buy a specified quantity, if the auction ends at a higher yield, the bidder can receive full benefits of buying at that higher yield (Garbade and Ingber, 2005; Nyborg and Sundaresan, 1995). However, there are risks involved and the procedures can be dangerous in that once the bidding yields stay above the clearing rates, the competitive bids are voided. Naturally a question arises: why do investors submit competitive bids rather than noncompetitive bids, when there are no price discrepancies between the two types of bids? The main reason is that with competitive bids, investors can be influential of the awarding yields. First of all, informed investors, such as sellers of the forward contract in the when-issued market, can take charge of the auction by entering their demand schedules based on private information. Even in cases of failing the auctions, they can still purchase Treasury securities in the secondary market or in the repo market, to fulfill obligations, i.e., executing the forward contract. With noncompetitive bids, rather than playing a leading role in the auction, those informed traders would be dominated by other participants. Secondly, submitting competitive bids is an effective approach to control the possible yields. This is especially important to speculators, since the final yields are more important than the amounts won at the auction (Fleming, 2007).In sum, competitive bidders must juxtapose the risk of unsuccessful bids with the reward of receiving better yields for successful bids.

To use competitive bids effectively, bidders can submit bids with low yields in order to win the auction with confidence. Otherwise, investors must face certain risk by submitting bids with high yields for a better price. Thus, when the market is competitive, i.e., shares provided from the auction are far fewer than the amount needed, bidders are expected to submit more low bids than usual, resulting in the distribution of bids skewed to the left. In other words, the dispersion of bids on the higher yield side tends to be narrower in the competitive market than in an easy market. Thereby, bid dispersion on the high yield side can be viewed as a proxy for the demand of Treasury securities at auction (Goldreich, 2007). A lower dispersion indicates of a greater demand.

Meanwhile, demand at auction can affect the post-auction secondary market as well as the when-issued market, both of which are integral parts of the entire auction process. Das and Sundaram (1996) demonstrate in a theoretical framework that without the secondary market, the winner's curse can be reduced, leading to more aggressive bidding and greater revenues for the Treasury. The presence of the secondary market merely intensifies this effect because it becomes less costly for the buyers to submit high bids. For instance, unsuccessful bidders with short position can fill orders with the close substitute securities in the secondary market prior to the issuance of the new securities to winners at auction. When-issued market is another avenue to purchase securities prior to the issuance of the new securities (Mercer et al. (2011), and Nandi (1997)).On the other hand, primary dealers generally buy large quantities of securities at auction and then sell them in the secondary market. Some of those securities are sold after a security is issued and others are sold before issuance in the when-issued market (Fleming, 2007). Greater buying pressures from failed bidders in the auction are more likely to drive up prices and thereby drive down yields after the auction. This outcome is consistent with Chatterjea and Jarrow (1998)'s prediction of a price bubble after the auction of U.S. Treasury securities based on a game theoretic equilibrium model. Thus, when demand at auction is high, a condition suggestive of a higher level of unfilled bids, the price in the secondary market could also be increasing and there would seem to exist arbitrage opportunities.

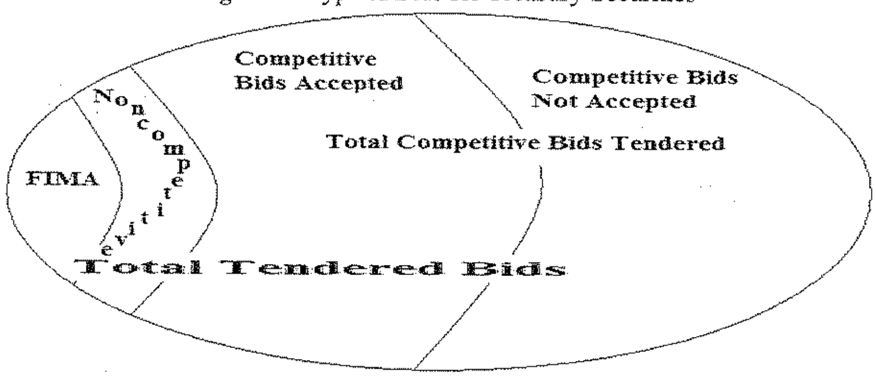
Furthermore, a higher bid-to-cover ratio indicates greater demand at auction and thus implies a higher return in the secondary market. Hence, bid-to-cover ratio is expected to be positively related to post auction returns. However, only unfilled orders from the auction are important. When there is a high noncompetitive total ratio or a high competitive acceptance rate, the percentage of unfilled orders tends to be low. Thus, we hypothesize that post-auction returns are negatively related to noncompetitive total ratio as well as competitive acceptance rate. Of note, lower dispersion of yields can hint of greater possibility of collusion or market manipulation (Bikhchandani et al., 2000; Chatterjea and Jarrow, 1998; Klemperer, 2002).

Bid Composition and Demand at Auction

In this study, we investigate the demand for Treasury securities at auction and its influence on the secondary market over the period from October 1998 through July 2010. In October 1998, the U.S. Treasury launched a uniform price auction system for new issues of Treasury securities, under which, all Treasury securities are awarded at the same finalized market clearing rate (Garbade and Ingber, 2005). The announcement and results of each auction are provided in the Treasury Direct website. We combine all the Treasury securities into one file. The final dataset has a total of 1,927 observations for the study period.

As discussed in Section Two, bidders can submit either noncompetitive bids or competitive bids (yields) in pursuit of obtaining the security purchase they are seeking. Bikhchandani et al. (2000) find that primary dealers are more informed and thus tend to submit competitive bids, whereas individual investors are uninformed and typically submit noncompetitive bids. Indeed, primary dealers not only have information about the prices of the when-issued contracts which is available to all investors as well as to the financial press, but also maintain the demand schedules for his customers, such as pension funds and other institutional investors. However, due to data availability, we cannot divide bidders into these groups but instead investigate bidding strategies on an aggregated level. In specific, we examine how the noncompetitive total ratio and competitive acceptance ratio change in the sample period and then study their impact on demand at auction. Competitive acceptance ratio measures the percentage of competitive bids that are accepted. It equals to the number of accepted competitive bids over total competitive bids. Noncompetitive total ratio equals to the number of noncompetitive bids over total tendered bids excluding Foreign and International Monetary Authority (FIMA) account. FIMA is mainly the account for foreign governments and therefore is excluded in this study. FIMA bids are noncompetitive in nature. An example of the auction results is shown in the Appendix. Figure 1 shows the relations among noncompetitive bids, accepted competitive bids, competitive bids tendered, FIMA, and total bids tendered. Of note, total bids tendered are the sum of FIMA bids, noncompetitive bids and total competitive bids. The bid-to-cover ratio is calculated by dividing the sum of FIMA bids, noncompetitive bids and accepted competitive bids by total tendered bids.

Figure 1: Type of Bids for Treasury Securities



To secure bids, investors can choose between noncompetitive bids and low yield competitive bids. Figure 2 and Figure 3 show the means of the noncompetitive total ratios, competitive acceptance ratios, and total acceptance ratios by year and by security type, respectively. Total acceptance ratio measures the percentage of tendered bids that are accepted, excluding FIMA bids. It is similar to the bid-to-cover ratio, except for the FIMA bids.

Total acceptance ratio = total accepted bids / total tendered bids excluding FIMA bids
= (accepted competitive bids + noncompetitive bids) / (total competitive bids+ noncompetitive bids) (1)

Clearly, less than 50% of bids are accepted, with the peak of approximately 50% appearing in 2001 and with two year Treasury notes. Interestingly, the acceptance rate has fallen consistently since 2003. In 2010, less than 30% of total tendered bids were accepted. Furthermore, the majority of investors submit competitive bids. The average noncompetitive total ratio is consistently less than 5%, suggesting that over 95% of bids are competitive. This ratio also falls each year reaching its low in 2010, which suggests that noncompetitive bids may be passive as investors increasingly use competitive bids to manage yields. Among the total competitive bids, the relatively high acceptance rates occur in 2003 and 2008. After 2008 rates decline. Figures 2 and 3 show that while a higher percentage of competitive bids have been submitted in recent years fewer have been filled. This finding suggests that auctions for Treasury securities have become more intensified during recent years.

As discussed in Section Two, the demand at auction can be proxied by bid dispersion on the high yield side. In specific, when bid dispersion is lower, demand at auction tends to be higher and thereby fewer competitive bids are expected to be filled. Thus, competitive acceptance ratio, the measure of the percentage of winning competitive bids out of total competitive bids tendered, is expected to be negatively (positively) related to the demand at auction (bid dispersion). Likewise, the noncompetitive total ratio, which shows the percentage of noncompetitive bids out of total bids except the FIMA accounts, is hypothesized to be positively associated with bid dispersion. Bid-to-cover ratio is the ratio of aggregate bids to supply and captures the extent of competition in the auction. We thereby hypothesize that demand at auction (bid dispersion) is positively (negatively) related to bid-to-cover ratio.

Figure 2: Profile of Means of Bid Composition Ratios by Year

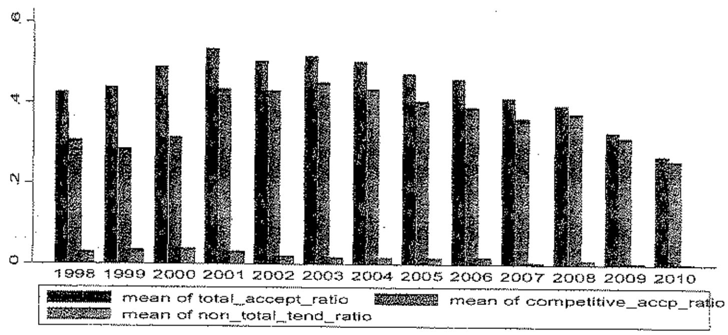
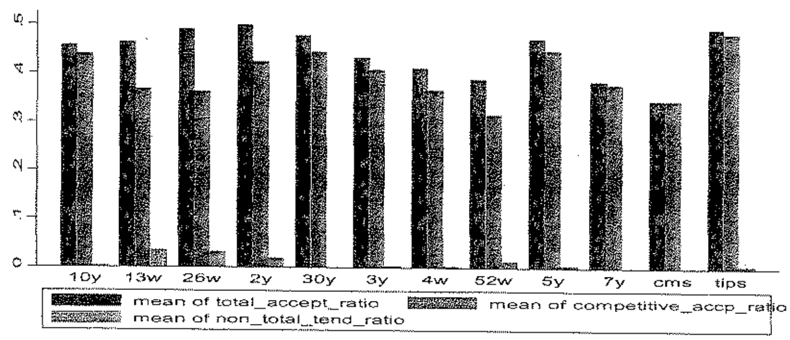


Figure 3: Profile of Bid Composition Ratios by Security Type



The hypotheses are summarized as follows.

H_1: Demand at auction (bid dispersion) decreases (increases) with the percentage of competitive bids that are accepted out of total submitted competitive bids.

H_2: Demand at auction (bid dispersion) decreases (increases) with the percentage of noncompetitive bids out of total submitted bids except the FIMA account.

H_3: Demand at auction (bid dispersion) increases (decreases) with bid-to-cover ratio.

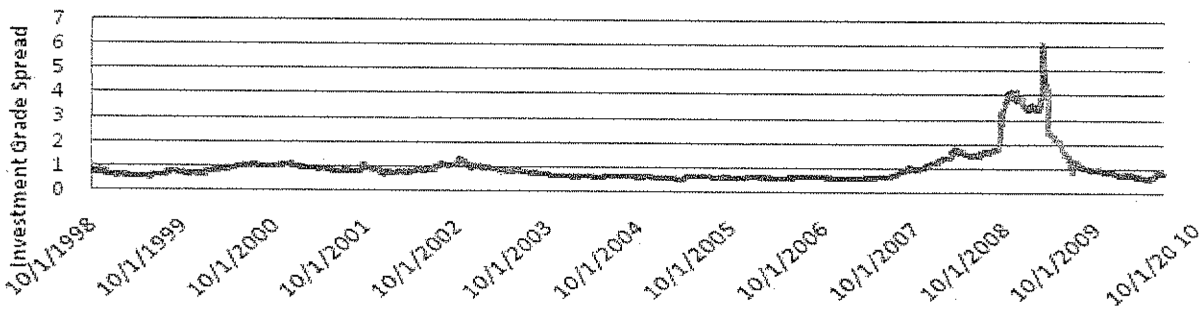
Koesrindartoto (2004) demonstrates in theoretical terms how to auction Treasury securities and discusses associated factors including participants' learning process, market structure, the volatility of the secondary market, and relative capacity. Malvey and Archibald (1998) argue that in addition to auction techniques, economic outlook and expectations regarding movements of interest rates tend to affect auction results. Hence, to reflect economic circumstances, we include in our analysis the AAA investment grade bond spread, measured by the difference between the AAA corporate bond yield and the spot Treasury bond yield. The higher this spread is, the weaker the economy is considered to be. When economy is expected to deteriorate, money tends to fly to perceived higher quality opportunities, resulting in the present context in higher demand for Treasury securities. Gilchrist and Zakrajsek (2011) find that when there is a rise in the excess bond premium during a financial downturn, the risk bearing capacity of the financial market tends to become less effective, leading to a contraction in the supply of credit and consequently to economic deterioration. Therefore, we expect demand at auction (bid dispersion) to be positively (negatively) related to investment grade bond spread (or risk premium).

Figure 4 displays the investment grade bond spread. The data is available on FRED provided by Merrill Lynch.

As expected, the investment grade bond spread is relatively stable until late 2007. During the financial crisis period, it rose sharply. Next, we empirically test these hypotheses.

Goldreich (2007) measures bid dispersion as the difference in yield space between the marginal winning bid and the median bid. He argues that a wide dispersion could result from disagreement among bidders about the value of securities. Godbout et al. (2002) measure bid dispersion as 100*(high yield – low yield) / low yield. They investigate the auction of Treasury securities in Canada where a multiple price system still dominates. They explain that high levels of auction bid dispersion are because of uncertainty in the financial markets, unexpected monetary policy intervention, and manipulation of the market by some participants.

Figure 4: Investment Grade Bond Spread from October 1998 to October 2010



Following Goldreich (2007), we measure bid dispersion by taking the differences between the high yield and the median yield. In specific, high and median are the accepted yields of the 100th percentile and the 50th percentile of the bids, respectively. High yield is thereby the final rewarding rate.

Bid dispersion = high yield - median yield
= highest accepted yields accepted yields 50th percentile. (2)

In this study, rather than emphasizing macroeconomic factors, we focus on three bidding ratios: the competitive acceptance ratio, the noncompetitive total ratio, and the bid-to-cover ratio. We also control for the economic environment or risk, as measured by the investment grade bond spread at the date that the auction results are announced. In addition, we take the log of bid dispersion, competitive acceptance ratio, and noncompetitive total ratio, since the values of those variables lie between 0 and 1.

We use the following fixed-effects models to test the association between bid dispersion and types of bids.

Bid dispersion $= \alpha + \beta_1$ * Competitive Acceptance Ratio + β_2 * Noncompetitive Total Ratio
+ β_3* Investment Grade Bond Spread+$\sum_{i=1}^{10} \beta i * Treasury\ Typei + \sum_{i=1}^{12} \beta i * Yeari + \varepsilon$ (3)

Bid dispersion $= \alpha + \beta_3$* Bid-to-Cover + β_4* Investment Grade Bond Spread +$\sum_{i=1}^{10} \beta i * Treasury\ Type\ i$
$+ \sum_{i=1}^{12} \beta i * Yeari + \varepsilon$ (4)

The correlations of the bid composition variables are reported in Table 1.

Table 1: Correlations of the Bid Composition Variables

Variables	*Competitive Ratio*	*Non-Competitive Ratio*	*Bid to cover ratio*	*Investment Grade Bond Spread*
Competitive Ratio	1.0000			
Non-Competitive Ratio	0.0196	1.0000		
Bid to Cover Ratio	-0.9679***	-0.1482***	1.0000	
Investment Grade Bond Spread	0.0009	-0.1872***	0.0013	1.0000

*** indicates statistical significance at 1% level.

Of note, the bid to cover ratio is highly negatively correlated with the competitive ratio.

The estimation results are reported in Table 2.

The results show that bid dispersion, the proxy for auction demand, increases with both competitive acceptance ratio and noncompetitive total ratio, at the 1% statistical significance level. Moreover, the coefficient of bid-to-cover ratio is negative and significant as expected. The results are consistent with the hypotheses. The results further demonstrate that when the spread between investment grade bonds and Treasury bonds increases, bid dispersion decreases, whereas demand at auction increases. In sum, the results are basically supportive of our hypotheses, suggesting that lower percentages of accepted competitive bids and noncompetitive bids tend to reflect higher demand for Treasuries at auction. Higher bid-to-cover ratio is associated with greater demand at auction as well.

Table 2: Regression Results to Test the Demand for Treasury Securities at Auction from the Perspective of Bid Composition

	Model 1		*Model 2*		*Model 3*		*Model 4*	
Variables	*Coefficient*	*T stat*	*Coefficient*	*T stat*	*Coefficient*	*T stat*	*Coefficient*	*T stat*
Competitive ratio_log	0.7048***	8.70			0.6986***	9.09		
Noncompetitive ratio_log	0.0671***	3.57					0.0817***	4.28
Bid cover ratio			-0.2464***	-8.57				
Investment Bond Spread	-0.0659**	-2.39	-0.6208**	-2.22	-0.0571**	-2.06	-0.0358	-1.28
Four week bill	-0.0589	-0.45	-0.0091	-0.07	0.0066	0.05	-0.3699**	-2.89
Thirteen week bill	-0.0972	-0.67	0.0856	0.68	0.1372	1.08	-0.4035***	-2.82
Twenty six week bill	-0.3757**	-2.55	-0.1942	-1.49	-0.1457	-1.11	-0.7294***	-5.05
Fifty two week bill	-0.3833**	-2.39	-0.2749	-1.75	-0.2465	-1.57	-0.6201***	-3.85
Two year notes	-0.2585*	-1.80	-0.0953	-0.71	-0.0760	-0.57	-0.4504***	-3.11
Three year notes	-0.2622	-1.59	-0.2110	-1.28	-0.1895	-1.15	-0.4045**	-2.42
Five year notes	-0.1637	-1.18	-0.0826	-0.60	-0.0803	-0.58	-0.2951**	-2.09
Seven year bond	0.0269	0.13	-0.0286	-0.14	0.0116	0.06	0.0083	0.04
Ten year bond	-0.1993	-1.41	-0.1457	-1.03	-0.1428	-1.01	-0.3325**	-2.33
CMS	0.1637	1.12	-0.0713	-0.54	-0.0844	-0.64	-0.0420	-0.28
Year 1999	-0.4409***	-3.31	-0.4568***	-3.40	-0.4467***	-3.33	-0.4952***	-3.66
Year 2000	-0.0420	-0.32	-0.0558	-0.41	-0.0354	-0.26	-0.04362	-0.32
Year 2001	0.2411*	1.79	0.2370	1.75	0.2062	1.52	0.5186***	3.88
Year 2002	-0.0304	-0.22	-0.0191	-0.14	-0.0607	-0.45	0.2595*	1.93
Year 2003	-0.0043	-0.03	0.0166	0.12	-0.0359	-0.26	0.3132**	2.34
Year 2004	0.1804	1.33	0.1591	1.18	0.1141	0.84	0.4756***	3.55
Year 2005	0.0554	0.40	0.0800	0.58	0.0534	0.39	0.2806**	2.04
Year 2006	0.2865**	2.12	0.2940**	2.16	0.2770**	2.04	0.4786***	3.52
Year 2007	0.2560*	1.80	0.2731*	1.93	0.2472*	1.75	0.3607**	2.50
Year 2008	0.4827***	3.53	0.4915***	3.56	0.4617**	3.35	0.5934***	4.28
Year 2009	0.3479***	2.57	0.3173**	2.32	0.2730**	2.01	0.3163**	2.29
Year 2010	0.3039**	2.22	0.2429*	1.78	0.1769	1.31	0.2040	1.47
Intercept	0.4342**	1.99	-0.0450	-0.24	-0.0144	-0.08	-0.1053	-0.49
R^2	19.67%		18.11%		18.48%		16.47%	
Adjusted R^2	18.61%		17.12%		17.49%		15.42%	
F value	18.62***		18.29***		18.73***		15.63***	
Number of observations	1,927		1,927		1,927		1,927	

***, ** and * represent 1%, 5% and 10% statistical significance level, respectively.

Post-auction Returns of Treasury Securities

Investors can trade Treasury securities in three essential markets: the when-issued market for forward trading of Treasury securities, the auction market, and the secondary market. Immediately following the announcement of a forthcoming auction, market participants start trading the new security on a when-issued basis. This market enables participants to hold contracts for the purchase and sale of a new security prior to the issuance of the security and thereby works as a path to reduce price uncertainty (Garbade and Ingberm, 2005; Goldreich, 2007). The when-issued market, the auction and the secondary market constitute the entire auction process for Treasury securities.

Here, we focus on the price changes in the same day in the secondary market after the releasing of the auction results. Secondary market participants are often divided into two parts: the sell side and the buy side. The primary securities dealers constitute the sell side, while the diverse group of final users of Treasury bonds constitutes the buy side. The buy side includes those who use Treasuries for speculating as well as for hedging purposes, such as commercial and investment banks, insurance companies and pension funds.

When demand at auction is high, failed bidders can have their orders filled with a close substitute securities in the secondary market on the same day which would presumably generate positive aftermarket returns. Thus, post-auction returns in the same day are expected to be positively related to demand at auction. Of note, lower bid dispersion indicates of higher demand at auction.

H_4: When demand at auction is higher, the same day post-auction returns increase.

As shown in Section Three, bid composition is associated with demand at auction. This raises an interesting question with respect to the relation of post-auction return and bid composition. We use the daily yields of Treasury securities from the US Treasury website. The Treasury securities in the secondary market are close substitutes of the Treasury securities being auctioned. They were originally issued with a longer time until maturity than the current issue but now have the same time remaining until maturity as the security currently being issued. This type of security would not be a perfect substitute because it may have different coupon rates. Further, since it is an off-the-run security, it is less liquid than the on-the-run security. Nevertheless, we exclude TIPs, CMS, and thirty year bonds, because the close substitutes do not exist. Our final dataset includes a total of 1,362 observations, covering the period from October 1998 to July 2010.

Post-auction return in the same day is measured as the difference between the awarding yield at auction, the highest accepted yields, and the final yield in the same day in the secondary market (Nyborg and Sundaresan, 1995; Cammack, 1991).Of note, the new securities are expected to be delivered at the issuing date which is several days after the announcement of the auction results.

Post-auction return = highest accepted yields at auction - yield in secondary market same day

Figure 5 and Figure 6report the profiles of the post-auction returns in the same day by type of Treasury securities and by years, respectively.

Figure 5: Medians of the Post-auction Return on the Same Day by Type of Treasury Security

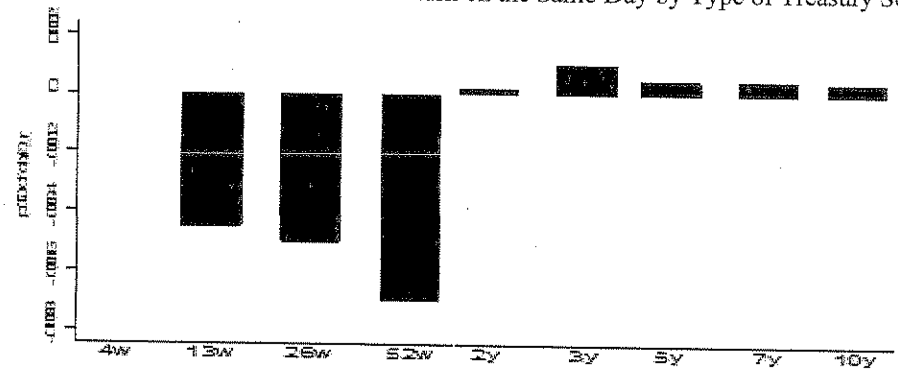


Figure 6: Medians of the Post-auction Return on the Same Day by Year

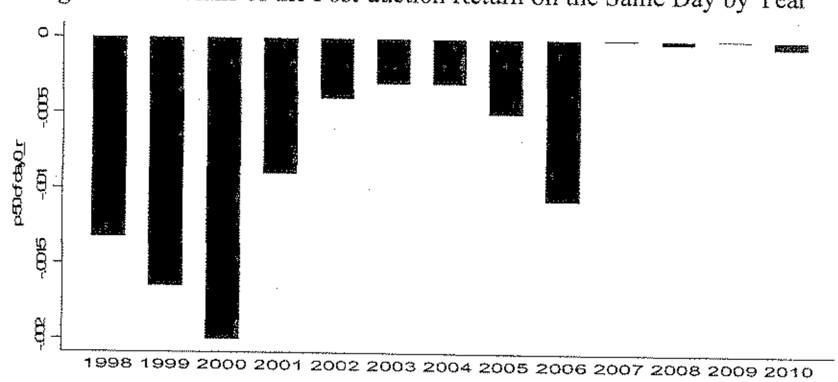


Figure 6 shows clear variation of post-auction returns by year, with the peak and the bottom appearing in 2009 and in 2000, respectively. Similarly, there are variations of post-auction returns by security type. The median returns for Treasury bills are much less than those with longer terms. Thus, it would be helpful to consider the effects of year and type. Of note, as shown in the above Figures, the median post auction returns are in general negative. This is not consistent with Chatterjea and Jarrow (1998)'s theoretical predication of a price bubble after the auction. The regression analysis provided below further investigates the post auction returns from the perspective of demand at auction.

As discussed in Section Two, we expect post-auction returns in the same day to be positively (negatively) related to demand at auction (bid dispersion). Further, we hypothesize that post-auction returns are positively (negatively) related to bid-to-cover ratio (competitive acceptance ratio as well as noncompetitive total ratio). Of note, we control for economic environment or risk by investment grade bond spread. To test those hypotheses, we use the following fixed-effects model.

$$\text{Post-auction return} = \alpha + \beta_1 * \text{bid dispersion} + \beta_2 * \text{Investment Grade Bond Spread} + \sum_{i=1}^{7} \beta i * TreasuryTypei + \sum_{i=1}^{13} \beta i * yeari + \varepsilon \quad (5)$$

$$\text{Post-auction return} = \alpha + \beta_1 * \text{Bid Dispersion} + \beta_2 * \text{Competitive Acceptance Ratio} + \beta_3 * \text{Noncompetitive Total ratio} + \beta_4 * \text{Investment Grade Bond Spread} + \sum_{i=1}^{7} \beta i * Treasury\ Typei + \sum_{i=1}^{13} \beta i * Yeari + \varepsilon \quad (6)$$

$$\text{Post-auction return} = \alpha + \beta_1 * \text{bid dispersion} + \beta_2 * \text{bid cover ratio} + \beta_4 * \text{Investment Grade Bond Spread} + \sum_{i=1}^{7} \beta i * TreasuryTypei + \sum_{i=1}^{13} \beta i * yeari + \varepsilon \quad (7)$$

Of note, in the above models, we take the log of the ratios except for bid-to-cover ratio, which is always greater than one. The estimation results with respect to post-auction returns are provided in Table 3.

Table 3: Regression Results Regarding Same Day Post-auction Returns after Auction

Variables	*Model 1* *Coefficient*	*T stat*	*Model 2* *Coefficient*	*T stat*	*Model 3* *Coefficient*	*T stat*
Bid dispersion (log)	-0.0001***	-2.83	-0.0001***	-4.21	-0.0001***	-3.84
Competitive ratio (log)			0.0005***	5.85		
Noncompetitive ratio (log)			0.0001***	2.57		
Bid-to-cover ratio					-0.0001***	-3.93
Investment Bond Spread	0.00004	1.48	0.0001**	2.22	0.00003	1.27
Thirteen week bill	-0.0003**	-2.49	-0.0005**	-3.04	-0.0003*	-1.96
Twenty six week bill	-0.0006***	-4.65	-0.0008***	-4.46	-0.0005***	-3.90
Fifty two week bill	-0.0010***	-6.54	-0.0009***	-6.61	-0.0009***	-6.04
Two year notes	0.0004***	2.76	0.0002	1.05	0.0004	3.13
Three year notes	0.0002	1.28	0.0001	0.78	0.0002	1.58
Five year notes	0.0003**	2.07	0.0002	1.37	0.0003**	2.40
Ten year bond	0.0003	0.98	0.0002	1.16	0.0002	1.32
Year 1999	-0.0005***	-4.83	-0.0005***	-4.89	-0.0005***	-4.68
Year 2000	-0.0010***	-9.15	-0.0010***	-9.89	-0.0010***	-9.30
Year 2001	0.0002**	1.97	0.00002	0.18	0.0001	0.74
Year 2002	0.0007***	6.44	0.0005***	4.43	0.0005***	4.88
Year 2003	0.0008***	7.28	0.0005***	5.09	0.0006***	5.51
Year 2004	0.0007***	6.44	0.0005***	4.50	0.0005***	4.79
Year 2005	0.0004***	3.29	0.0002**	2.08	0.0003**	2.23
Year 2006	0.0001	0.42	-0.0001	-0.65	-0.00005	-0.43
Year 2007	0.0004***	3.09	0.0004***	2.88	0.0004***	2.77
Year 2008	0.0010***	8.28	0.0010***	8.36	0.0009***	8.03
Year 2009	0.0009***	7.95	0.0010***	8.47	0.0009***	8.26
Year 2010	0.0010***	8.92	0.0012***	9.95	0.0010***	9.57
Intercept	-0.0014***	-5.07	-0.0007**	-2.05	-0.0013***	-4.90
F value	133.11***		136.75***		129.12***	
R^2	67.58%		70.16%		69.95%	
Adjusted R^2	67.07%		69.64%		67.42%	
No. of observations	1,362		1,362		1,362	

***, ** and * represent 1%, 5% and 10% significance level, respectively.

The first model tests the association of demand at auction, proxied by bid dispersion, and post-auction returns. The coefficient of bid dispersion is negative and statistically significant. This is consistent with our expectation, which states that when bid dispersion is lower, indicating of higher demand at auction, post-auction returns in the same day tend to be higher. The second model tests the determinants of the post auction returns from the perspective of bid compositions, including competitive acceptance ratio and noncompetitive total ratio. The coefficients for competitive acceptance ratio and noncompetitive total ratio are both positive and statistically significant at 1% level. However, this is not in supportive of our hypothesis. Lastly, the third model includes variables of both bid dispersion and bid composition. The coefficient of the bid-to-cover ratio is negative and statistically significant at 1% level. This is inconsistent with our hypothesis, which stating that when bid-to-cover ratio is higher, more bids are left unfilled and those unsuccessful bidders might rush to the secondary market to purchase Treasury securities. The above inconsistence with expectations could be due to the influence of the when-issued market, from which investors can still purchase and sell forward contracts of Treasury securities before the actual issuance of the securities after auction (Pichler and Stomper, 2009; Bikhchandani et al. ,2000; Fleming, 2007).

In sum, we *do* find evidence regarding the positive relation between post-auction returns and demand at auction as proxied by bid dispersion. The results tend to suggest that when demand for Treasuries at auction is higher, as observed from a lower bid dispersion, investors tend to pay higher prices to purchase the Treasury securities in the secondary market than at auction.

Conclusion

In this study, we analyze the demand for Treasury securities at auctions from October 1998 to July 2010. During this period, the US Treasury adopted the uniform price auction system. With the new auction mechanism, revenues for Treasury are expected to increase and "winner's curse" are supposed to be eliminated. We investigate such demand from the perspective of types of bids submitted and the influence of demand at auction in the secondary market. So far as we know, this topic is still new in the literature.

We estimate the fixed-effects models and find evidence that the demand at auction, measured by bid dispersion, are positively related to bid-to-cover ratio and are negatively associated with competitive acceptance ratio as well as noncompetitive total ratio. We further find that the post-auction returns are positively related to the demand at auction proxied by bid dispersion.

Lastly, the findings suggest of arbitrage opportunities from the price discrepancy between the auction and the secondary market when demand is high. However, the securities traded in the secondary market right after the auctions are off-the-run which are generally less liquid than their on-the-run counterparts. Thus, the price discrepancy could be just the liquidity premium. The findings suggest that failed bidders buy Treasury securities from the secondary market to fill their orders. Of note, unsuccessful bidders can also purchase securities from the when-issued market, by trading in the forward Treasury market prior to the issuance of Treasury securities from auction.

Future studies can endeavor to extend Chatterjea and Jarrow (1998) and apply game theory to explore the optimal bidding strategies at auction. Another avenue for future research can focus on the information integration, especially on how information spreads among the three essential markets: the when-issued market, the auction and the secondary market.

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Appendix

An Example of Treasury Security Auction Results

Department of the Treasury • Bureau of the Public Debt • Washington, DC 20239
TREASURY SECURITY AUCTION RESULTS
BUREAU OF THE PUBLIC DEBT - WASHINGTON DC
FOR IMMEDIATE RELEASE CONTACT: Office of Financing
February 11, 2003 202-691-3550

RESULTS OF TREASURY'S AUCTION OF 5-YEAR NOTES

Interest Rate: 3%	Issue Date: February 18, 2003
Series: E-2008	Dated Date: February 15, 2003
CUSIP No: 912828AT7	Maturity Date: February 15, 2008
High Yield: 3.029%	Price: 99.866

All noncompetitive and successful competitive bidders were awarded securities at the high yield. Tenders at the high yield were allotted 71.96%. All tenders at lower yields were accepted in full.
Accrued interest of $ 0.24862 per $1,000 must be paid for the period from February 15, 2003 to February 18, 2003.
AMOUNTS TENDERED AND ACCEPTED (in thousands)

Tender Type	Tendered Accepted	Accepted
Competitive	$ 33,895,105	$ 23,732,654
Noncompetitive	237,378	237,378
FIMA (noncompetitive)	30,000	30,000
SUBTOTAL	34,162,483	24,000,032 1/
Federal Reserve	3,483,950	3,483,950
TOTAL	$ 37,646,433	$ 27,483,982

Median yield 2.980%: 50% of the amount of accepted competitive tenders was tendered at or below that rate. Low yield 2.900%: 5% of the amount of accepted competitive tenders was tendered at or below that rate.
Bid-to-Cover Ratio = 34,162,483 / 24,000,032 = 1.42
1/ Awards to TREASURY DIRECT = $145,222,000