Treasury Auctions: What Do the Recent Models and Results Tell Us?

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AUCTIONS, AS SELLING MECHANISMS, HAVE EXISTED FOR WELL OVER TWO THOUSAND YEARS AND HAVE BEEN USED TO SELL A WIDE SPECTRUM OF GOODS. THE ANCIENT BABYLONIANS SOLD WIVES THROUGH AUCTIONS, AND THE LEGIONS OF ANCIENT ROME OFTEN SOLD THEIR BOOTY THROUGH AUCTIONS. CURRENTLY, AUCTIONS ARE EMPLOYED TO SELL OBJECTS AS DIVERSE AS ARTWORK, MINERAL RIGHTS, CUT FLOWERS, GOLD, TOBACCO, THOROUGHBRED HORSES, AND CORPORATIONS.

One of the most important auction markets in the world today is that of U.S. Treasury securities; approximately $2 trillion worth of Treasury securities was auctioned in 1995. As in other auctions, a set of rules determines how bids are used to determine prices; this set of rules makes up the format of the Treasury auction.

A long-standing debate (dating back to the early 1960s) has centered on the selection of an appropriate auction format for various Treasury securities, one that would be least subject to possible manipulations by any individual trader or a cartel and also result in the highest possible revenues for the Treasury.[1] This debate received fresh impetus after the infamous May 1991 auction for two-year Treasury notes, which led to a squeeze in the available supply of these securities in the postauction, or secondary, market. At this auction Salomon Brothers, one of the biggest primary dealers, grossly violated the maximum amount of the note that it could buy (U.S. Treasury 1992). As a result, the two-year notes started trading at abnormal premiums in the secondary market. In other words, following the auction, the secondary market for the two-year notes suddenly became very illiquid. An illiquid secondary market could not only increase the Treasury's cost of financing in subsequent auctions but is also detrimental to the Federal Reserve's ability to carry out its open market operations in the most efficient manner. An understanding of the various auction formats and what they entail for the Treasury's cost of financing, squeezes, and market liquidity is important to all participants of the Treasury auction market and, to some extent, everyone interested in Treasury securities.

The nature of Treasury auctions differs from many other types of auctions. Most consist of the sale of a single good that is not traded before or after the auction. These auctions have been the subject of considerable study. In contrast, in a Treasury auction, multiple units of the same good are auctioned, and the auction is preceded by trading in a forward market, in which one can

obtain the to-be-auctioned securities at a price fixed in advance of the auction. The auction is followed by active trading in a secondary market. It is therefore informative to look at models that take into account these unique features of Treasury auctions. The vulnerability of any auction format to collusion among bidders and the revenue superiority of one auction format to another could very well depend on these particular features of the Treasury auction market.

This article seeks to explain the current understanding of Treasury auctions in light of recent theoretical research that takes into account the distinguishing features of Treasury auctions and ongoing empirical research that looks at these issues. It also informally explores, in the context of current research findings, the effects of certain contemplated changes in existing auction formats on collusion and squeezes and hence on the Treasury's borrowing costs. The article first provides a brief description of the different types of auctions and the structure of the market for Treasury auctions. The discussion then turns to the current theoretical models that incorporate the unique features of Treasury auctions—what they imply for the two formats currently used to auction securities and related empirical evidence. The final section analyzes the possible effects of some of the contemplated changes in the present auction mechanism.

The Market for Treasury Auctions

This section briefly reviews some of the institutional details of the Treasury auction market. (*The Joint Report on the Government Securities Market* [U.S. Treasury 1992] and Stigum 1990 provide more detailed coverage.) Box 1 describes some of the commonly used auction formats, namely, the English auction, the Dutch auction, the first-price sealed-bid auction, and the second-price sealed-bid auction. The two currently used formats for Treasury auctions, the uniform-price auction and the discriminatory auction, are related to but somewhat different from the first-price and second-price auctions.

Bidders in Treasury auction declare themselves to be one of two types, competitive and noncompetitive. Competitive bidders, the bulk of whom are the thirty-nine dealers designated as primary dealers by the Federal Reserve Bank of New York, submit sealed bids specifying the dollar amounts of the security the bidder is willing to buy at each yield.[2] Noncompetitive bidders submit a quantity bid, up to $1 million for bills and $5 million for notes and bonds, but do not specify any yield; the total amount of noncompetitive bids is subtracted from the dollar amount of the security to be auctioned, and what remains is available for competitive bidding.[3]

Box 2 illustrates how bidders are awarded securities in a Treasury auction. A bid is a demand schedule that specifies the dollar amount of the security the bidder is willing to buy at each yield. In a uniform-price auction, all bidders pay the same yield (the market-clearing yield) for the entire quantity they are awarded. In a discriminatory auction, each bidder pays for a quantity of the accompanying yield in the demand schedule, as discussed in Box 2. Currently, only the two- and five-year notes and the inflation-indexed bonds are auctioned through the uniform-price procedure.[4] For all other bills and bonds, the discriminatory format is used.

As soon as the Treasury announces the total dollar amount of the particular security to be auctioned, trading begins in a forward market, called the when-issued market. An investor, instead of bidding at the auction, can lock in a yield in the when-issued market by buying the when-issued contract. The seller of the forward contract is under contractual obligation to deliver the Treasury security to the buyer of the contract at the time the Treasury delivers the securities to the successful bidders.[5] After the auction, an active secondary market develops for the newly auctioned security, often called an on-the-run security. The secondary market also trades close substitutes of the newly auctioned security, namely, securities from a previous issue of different maturity (off-the-run securities) that have maturities very close to the newly issued security's maturity. In general, on-the-run securities tend to be more liquid than off-the-run securities of comparable maturity.

There is also a repurchase (repo) market for Treasury securities (see Syron and Tschinkel 1987). It is a market for short-term debt for which a specific Treasury security is held as collateral by a lender. In general, borrowers who want funds from the repo market place their securities as collateral and agree to repurchase these securities at a later date (often overnight) at

1. *Note that the concept of the Treasury's maximizing revenue is equivalent to its minimizing the cost of debt.*
2. *Treasury securities dealers with whom the Federal Reserve trades directly as part of its open market operations are called primary dealers. Trading by the primary dealers accounts for the bulk of trading in the secondary market. To become a primary dealer, a firm must also be committed to bidding nontrivial amounts at the Treasury auctions.*
3. *Noncompetitive bids, on average, compose about 15–20 percent of the total dollar amount of an auction.*
4. *The Treasury conducted six uniform-price auctions of long-term bonds during 1973 and 1974 but discontinued those thereafter. In fact, in one of the auctions, the tendered amount did not exceed the intended dollar amount of the issue.*
5. *Currently, there is a limit on the amount of securities a bidder can get at a single auction. Inclusive of positions in the futures, forwards, and the when-issued market, a bidder's net position in an auction at any given yield may not exceed 35 percent of the total dollar amount of the auction.*

BOX 1

Commonly Used Auctions

In an **English (ascending-price) auction,** often employed to sell artwork or antiques, prices are progressively raised, either by the auctioneer or with the bidders placing their bids directly, until the object is sold to the bidder who stays at the last round.

The **Dutch (descending-price) auction,** used to sell cut flowers in Holland, among other things, is the direct opposite of the English auction—that is, prices are successively lowered.[1]

Unlike English and Dutch auctions, in which each bidder gets to observe the bids of all other bidders, in sealed-bid auctions, as the name suggests, the bidders submit sealed bids. In a **first-price sealed-bid auction,** the object is awarded to the highest bidder at the bid he submits.

In a **second-price sealed-bid auction,** the object is awarded to the highest bidder, but the winner pays the bid of the second-highest bidder.

1. "Dutch auction" in this article refers to auctions of this type only and not the uniform-price Treasury auction, as is the case sometimes.

a predetermined price. The predetermined price is higher than the amount loaned, the difference being the interest earned on the loan of short-term funds.

Winner's Curse

For bidders in a Treasury auction, the value of a security (that will be auctioned) is its resale price in the secondary market after the auction. The true value is an unobserved quantity (that is, a random variable) that is common across all bidders. Auctions of this type are known as common-value auctions.

Winning a bid award in a common-value auction is often associated with a phenomenon known as the winner's curse. In a first-price auction of this type, the winning bidder is the one who has the highest estimate of the object's true value. Having won the auction may not be particularly good news as it implies that everyone else's estimate of the true value was lower. The winner may well have overestimated the value and could suffer a loss in trying to sell the object. This winner's curse has been noted in auctions for off-shore oil rights and markets for baseball players, for example.[6] Realizing this possibility when bidding, bidders are likely to shade their bids below their estimates of the object's true value, and the result is a loss of potential revenue to the seller. A second-price auction, in which the winner pays the highest losing bid, mitigates the winner's curse by having the bidder pay the second-highest bid. Because the extent of bid shading is likely to be lower, it can also result in higher expected revenue for the seller than a first-price auction.[7]

Although Treasury auctions are for multiple units of the same good, they share certain common features with auctions for a single unit of a good in which the winner's curse is an important phenomenon. A uniform-price Treasury auction is similar to a second-price single-unit auction because the winning bidders pay not necessarily their bid prices but a common market-clearing price, which could often be lower than their bid prices. On the other hand, a discriminatory Treasury auction is similar to a first-price single-unit auction because all winning bidders pay their bid prices. Given the similarity between second-price and uniform-price auctions, it is quite possible that the severity of bid shading is much lower in a uniform-price auction than in a discriminatory auction, leading some to argue that a uniform-price auction would be the better choice for the Treasury.

Uniform-Price or Discriminatory Auctions? The Traditional View

The debate regarding the revenue superiority of uniform-price auctions over discriminatory auctions was first initiated by Friedman (1960). He argued that the possibility of the winner's curse in discriminatory auctions discourages participation by relatively uninformed bidders, in turn leading to reduced competition and the possible formation of a cartel consisting of a small number of bidders. Another argument in favor of a uniform-price auction is based on the notion that bidders bid more aggressively in uniform-price auctions than in discriminatory auctions. These points have been elaborated in Bikhchandani and Huang (1989), Chari and Weber (1992), and Smith (1992). However, these researchers modeled Treasury auctions as single-unit auctions and ignored the fact that bidders in Treasury auctions can submit demand schedules.

Although Chari and Weber do recognize that a multiple-unit auction is different from a single-unit auction, the distinction is minimized by their claim that the economic logic of the arguments for the single-unit auction seems likely to carry over to a multiple-unit auction.

In the aftermath of the Salomon episode, the Treasury switched from discriminatory to uniform-price auctions for two- and five-year notes on an experimental basis.[8] In fact, then Undersecretary of the Treasury for Finance Jeremy Powell stated that one of the primary reasons for switching was the "very substantial academic opinion that the single price auction could result in lower financing costs." Recent research suggests, however, that a uniform-price auction could actually benefit the Treasury less than a discriminatory auction because it allows bidders to submit demand schedules instead of bidding for the whole unit.

Uniform-Price or Discriminatory Auctions? Current Perspective and Models

As mentioned before, in a Treasury auction the competitive bidders submit demand schedules. It turns out that the ability to submit demand schedules conveys an important strategic advantage to bidders in uniform-price auctions, and it is one of the primary focuses of the recent research on Treasury auctions. Extending an important result by Wilson (1979), Back and Zender (1993) shows that uniform-price auctions may actually encourage implicit collusion among bidders and cost the Treasury money by awarding the auction at too low a price.

The following simple example illustrates the basic intuition of Back and Zender (1993). Assume that the Treasury is going to auction $10 billion worth of a one-year zero-coupon security and there are three risk-neutral bidders and no noncompetitive demand; the expected yield in the after-market will be 5 percent, and each competitive bidder agrees on that amount.[9] Suppose each of the bidders agrees to submit two bids, one for $3333 million at a yield of 6 percent and another for $6666 million at a yield of 20 percent. Given these bids, the uniform-price auction will clear at the higher yield of 20 percent (or equivalently at a lower price), which is bad news for the Treasury. Each bidder gets one-third of the $10 billion ($3333⅓ million) Treasury issue at 20 percent, a very lucrative outcome; implicitly each bidder is part of a cartel that divides the issue equally among its members. The usual problem with such cartels is that each member has an incentive to deviate and bid a slightly higher price than agreed by the cartel. The deviating member gets more volume (perhaps all the volume) at only a small loss in profits. Since the face value of the security that a bidder gets from this arrangement is $3333⅓ million and the associated yield is 20 percent, the cost of the securities is $(3333.33/1.2) million ≈ $2777.78 million. Similarly, the expected revenues from selling the securities at a yield of 5 percent is $(3333.33/1.05) million ≈ $3174.6 million. Therefore, each bidder's expected profit as a member of the cartel is $(3333.33) × (1/1.05 – 1/1.2) ≈ $396.82 million. If one of the bidders deviates and submits a bid of 19.99 percent, then he or she gets $3334 million of the issue, but the market-clearing yield drops to 19.99 percent.[10] As a result, expected profit drops to $(3334.0) × (1/1.05 – 1/1.1999) ≈ $396.67 million, which makes the bidder worse off than being part of the cartel. Similarly, cornering the whole issue or submitting any quantity greater than $3334 million will cause the yield to fall at or below 6 percent, both of which are less profitable than sticking to the cartel.

Now, consider a slightly different bidding arrangement in which each of the bidders changes the bid at $3333 million to 15 percent and everything else remains the same. This particular bidding arrangement will encourage a bidder to deviate and corner the whole issue by submitting just one bid for $10 billion at 14.99 percent. On these terms the expected profits from deviating, $(10000.0) × (1/1.05 – 1/1.1499) million ≈ $827.40 million, exceed the profits from sticking to the cartel. What exactly is the difference between the two bidding scenarios? Chart 1 shows that the demand schedules in the former arrangement are steeper than those in the latter. The steepness of demand schedules increases the cost of deviating from a cartel and sustains the collusion.

However, a collusive arrangement such as the one discussed above is difficult to sustain in a discriminatory auction. Because each bidder pays her bid yield for the quantity awarded out of her demand schedule, submitting steep demand schedules could turn out to be costly as a bidder ends up paying for the low-yield (high-price)–low-quantity points in her demand schedule.

6. See McAfee and McMillan (1987, 721) for some references.

7. In general, the revenue comparison between the first-price and second-price auctions could depend on the bidders' attitudes toward risk. See Milgrom and Weber (1982) for more details.

8. As of now, the experiment has been extended indefinitely.

9. Risk neutrality implies that, facing an uncertain yield in the after market, bidders care only about the expected/average level of yield. A risk-averse bidder would also care about the dispersion of the possible yields in the after market.

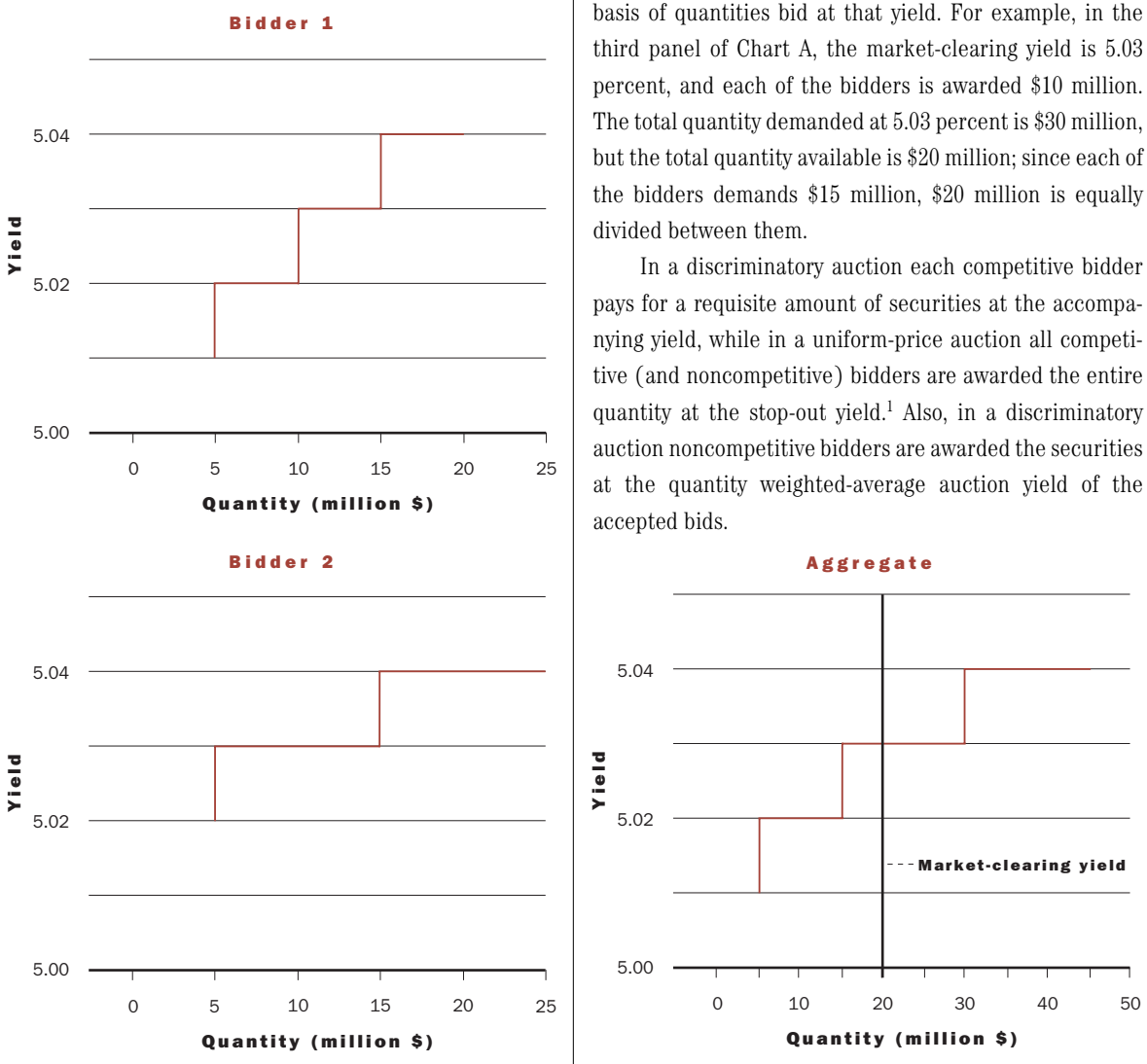
10. Each of the three bidders gets $3333 million (of the $10 billion issue) as each of them submits a bid at the low yield of 6 percent. However, the deviating bidder also gets an additional $1 million because the high bid of 19.99 percent is lower than those of the other two bidders at 20 percent, and the auction clears at 19.99 percent.

Bid Allocation in Treasury Auctions

Consider an auction in which $50 million worth of a Treasury security will be auctioned and there are two competitive bidders. Each bidder submits a demand schedule, that is, the dollar amount of the security that he or she is willing to buy at each particular yield as shown in Chart A. If the amount of noncompetitive bids is assumed to be $10 million, the quantity available to the two competitive bidders is $40 million. Starting at the lowest yield bid, the Treasury computes the total quantity demanded at each yield by adding the individual quantity demanded at each yield by the two bidders and arrives at an aggregate demand schedule, as in the third panel of Chart A; each bidder gets the entire quantity on his or her demand schedule at the accompanying yield, provided the total quantity demanded at the particular yield is less than the available supply. This process is repeated for an increasing sequence of yields as the Treasury works its way up the demand schedule of each bidder until the available supply is exhausted; the yield at which this happens is called the market-clearing or stop-out yield. At the market-clearing yield, if the total quantity demanded exceeds the available supply, each bidder is awarded a quantity prorated on the basis of quantities bid at that yield. For example, in the third panel of Chart A, the market-clearing yield is 5.03 percent, and each of the bidders is awarded $10 million. The total quantity demanded at 5.03 percent is $30 million, but the total quantity available is $20 million; since each of the bidders demands $15 million, $20 million is equally divided between them.

In a discriminatory auction each competitive bidder pays for a requisite amount of securities at the accompanying yield, while in a uniform-price auction all competitive (and noncompetitive) bidders are awarded the entire quantity at the stop-out yield.[1] Also, in a discriminatory auction noncompetitive bidders are awarded the securities at the quantity weighted-average auction yield of the accepted bids.

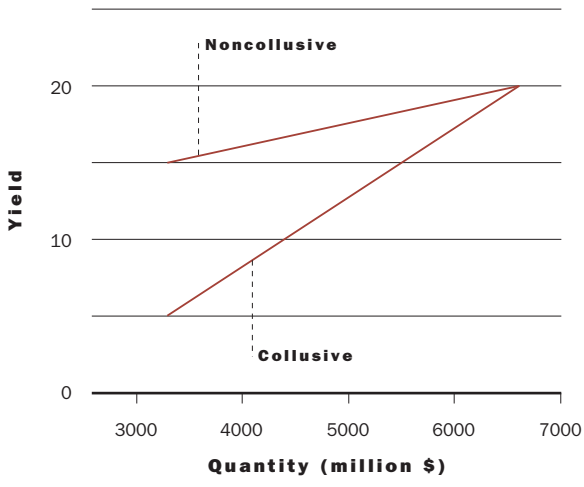
Chart A
Demand Schedules



1. *For example, in a discriminatory auction, bidder 1 gets $5 million at 5.01 percent, $10 million at 5.02 percent, and $10 million at 5.03 percent. In a uniform-price auction, both bidders get the entire amount of securities at 5.03 percent although they did bid lower yields.*

Indeed, Back and Zender (1993) show through a sophisticated model that a uniform-price auction could result in a loss of revenue to the Treasury as compared with the discriminatory auction if the bidders submit steep enough demand schedules in the uniform-price auction. The steepness of the demand schedules binds the bidders to a self-enforcing collusive arrangement; if anyone deviates from the cartel, then he or she earns lower expected profits. The interesting aspects of the Back-Zender model are that collusion takes place despite the bidders not being able to observe the bids of other bidders in a sealed-bid auction and the model considers only one auction at a time.[11] On this question of the effects of the steepness of demand schedules, Feldman and Reinhart (1995) document that the demand schedules in uniform-price gold auctions (conducted by International Monetary Fund) are steeper than those in discriminatory auctions

CHART 1
Collusive and Noncollusive Demand Schedules



Noncompetitive Bids

If there are noncompetitive bidders, competitive bidders do not know at the time they submit their bids the net amount of the Treasury security that will be available to them. The net amount available to competitive bidders is therefore a random quantity. The random supply represents a source of risk to the bidders in formulating and implicitly coordinating their bidding strategies to maintain collusion. In particular, some of the low-yield (high-price)–low-quantity points in steep demand schedules (if they wish to submit such schedules) that otherwise do not matter in terms of the clearing price in uniform-price auctions may actually clear the auction, costing the colluding bidders dearly. In the example discussed above, suppose the total noncompetitive bid is for $50 million. The net amount available to the three competitive bidders would be $950 million, and, given the bids, the auction would clear at 6 percent instead of at 20 percent as in the collusive outcome.

However, the Back-Zender model assumes that bidders are risk neutral; by definition, risk-neutral bidders do not care about the risk that noncompetitive bids may cause the low-yield points in their steep demand schedules to be realized as auction-clearing yields. Because they care only about their expected gain, competitive bidders are willing to submit steep demand schedules. Consequently, a uniform-price auction could be a worse choice for the Treasury than a discriminatory auction even with unpredictable noncompetitive demand.[12] Although most of the primary dealers are large financial institutions, many of them are not the very large, well-diversified corporations that seem to fit the risk-neutral description. Also, many of the competitive dealers are known to hedge interest rate risk, an activity not compatible with risk neutrality. It is therefore important to look at models in which bidders are risk averse.

What If Bidders Are Risk Averse?

Wang and Zender (1996) relax the assumption of risk neutrality of bidders; otherwise they retain the same assumptions as those of Back and Zender. The primary finding relevant for this article is that if the number of competitive bidders and the average level of the random competitive demand are sufficiently high, a uniform-price auction could yield higher revenues to the Treasury than a discriminatory auction despite the ability of the bidders to submit steep demand schedules. This result runs contrary to the general argument of Back and Zender and underscores the importance of risk neutrality in that model.

In the example used to illustrate the intuition of the Back-Zender model, it is clear that the profit per bidder in the collusive arrangement decreases with the addition of bidders because the issue is equally divided among the bidders. Therefore, an increase in the number of bidders would make such a collusive outcome more difficult to sustain in a uniform-price auction and may increase its desirability for the Treasury. The higher the amount of noncompetitive bids is, the lower the

11. In the parlance of game theory, the model is one of a single-period game. Normally, collusion among agents is easier to sustain in multiple-period games because the deviating agent in any period can be punished in a subsequent period.

12. Back and Zender (1993) do not analyze all possible game-theoretic equilibria (outcomes given rational actions of agents) and instead analyze only a tractable set of such equilibria. It remains possible that with risk-neutral bidders a uniform-price auction could actually be a better choice for the Treasury.

available supply is for competitive bidders and the higher the chances are that the auction will clear at the low-yield (high-price) points of the bidders' steep demand schedules. Therefore, if the amount of expected noncompetitive bids is high, risk-averse bidders may not be willing to take the risk of submitting steep demand schedules because such schedules increase the chances of unfavorable outcomes (to bidders). As a result the collusive outcome may not be realized and the Treasury would benefit.

Pre- and Postauction Markets

The preauction when-issued market and the postauction secondary market are integral parts of the entire auction process and may affect the analysis of possible collusion under uniform-price and discriminatory auctions. If bidders are committed to sell the to-be-auctioned securities in the when-issued market and fail to obtain a sufficient amount of them at the auction, they will have no alternative other than to buy these securities in the postauction market either through a repo or directly in the secondary market. However, often newly auctioned on-the-run securities trade "on special" in the repo market—that is, one has to lend funds at below-the-market rate to get these securities. They are also more expensive to buy in the cash secondary market than seasoned securities of comparable maturities. Thus, in formulating bidding strategies for an auction, bidders have to take into account their positions in the when-issued market and the possibility of buying the securities at a premium in the postauction market. A more complete model of Treasury auctions, therefore, would take into account the when-issued market, the auction itself, and the possibility of trading in the secondary market. Two recent studies by Wang and Vishwanathan (1996) and Chatterjea and Jarrow (1995) take into account the preauction and postauction markets in their models of Treasury auctions and are discussed below.

Wang and Vishwanathan (1996) model the entire auction process as consisting of three distinct markets: preauction when-issued trading, the auction itself, and postauction when-issued trading. They assume that competitive bidders can submit demand schedules at the auction but are averse to holding a large number of positions (long or short) at the end of the auction cycle. The assumption of aversion to large positions is not unrealistic because bidders do not want to be caught in a squeeze if they have substantial short positions and financing unsold long positions is costly. Consequently, bidders optimally restrain the steepness of their demand curves to avoid ending up with unwanted excess inventory (long or short). As in Wang and Zender (1996), Wang and Vishwanathan find that because of the diminished ability of bidders to submit steep demand curves, uniform-price auctions can generate more revenue for the Treasury than discriminatory auctions when the number of competitive bidders and the mean level of noncompetitive demand are high. An important aspect of the model is that it is able to address the issue of the temporal pattern of price volatility in the postauction when-issued market. The authors find that auction surprises elicit a higher response in discriminatory auctions than in uniform-price auctions. This result is consistent with empirical evidence of Belzer and Reinhart (1996), in which the surprise is measured by the difference between the average auction yield and the contemporary when-issued yield.

Chatterjea and Jarrow (1995) consider the preauction when-issued market and the postauction secondary market but ignore noncompetitive bids and do not allow for bidders (assumed to be risk neutral) to submit demand schedules; instead the bidders are allowed to submit bids only for the entire quantity to be auctioned. Although the bidders could end up getting less than the entire unit if there is a tie with other bidders, essentially the model is that of a single-unit auction. In a common-value single-unit auction with risk-neutral bidders, it is well known that a second-price auction is superior to a first-price auction because the extent of bid shading due to the winner's curse in the former is less. In keeping with this result, the authors find that uniform-price auctions (that are similar to second-price auctions) yield higher revenues to the Treasury than discriminatory auctions (that are similar to first-price auctions).

The theoretical papers that have been discussed so far take into account the strategic advantage that comes with submitting demand schedules or the institutional setup of the Treasury market. However, they have focused mainly on the revenue superiority of one auction format over another. They do not directly address the important issue of whether either of the auction formats (uniform-price or discriminatory) is more vulnerable to short squeezes that are often known to develop in the repo or the secondary market following an auction and, in fact, prompted the Treasury to consider alternative formats. Nor do they recognize the fact that bidders do communicate before the auction. These two issues are addressed next.

Communication among Bidders

It seems possible that competitive dealers indulge in mutual communication before submitting bids for an ensuing auction.[13] The theoretical models developed to date do not take into account such preauction communication, as otherwise the models are intractable. A feasible way to tackle the issue of bidder communication is to perform a controlled experiment that tries to replicate the actual auction

market. Experiments by Goswami, Noe, and Rebello (1996) suggest that, in the absence of communication, the uniform-price auction results in higher revenues for the auctioneer.[14] However, if bidders are allowed to discuss their future strategies, the outcomes of previous auctions, and so forth, collusive behavior emerges and the uniform-price auction generates a lower revenue than the discriminatory auction. If there is communication among bidders, one might conclude that discriminatory auctions could be a better choice for the Treasury in terms of revenue enhancement. Other empirical research (discussed below), however, does not find any significant differences in revenues between the two auction formats.

Short Squeezes

Quite often, repo rates on specific on-the-run issues are lower than overnight lending rates collateralized by similar securities. The difference between that overnight lending rate and the repo rate (collateralized by the specific security) measures the degree of "specialness" of that specific security; owners of securities on special can obtain overnight loans at a lower rate than those of other comparable securities. The occurrence of specials in the repo market is a common phenomenon and could be an outcome of the auction process itself. Dealers who have short positions in the when-issued market and fail to obtain the desired amount of securities at the auction have to acquire the securities either from the secondary cash market or the repo market. Sufficiently high demand for a specific security can increase the price and decrease the repo rate on the specific security. Additionally, deliberate acts of cornering an auction by an individual or a cartel could result in short squeezes and specials, as was the case with Salomon Brothers in the May 1991 two-year note auction.

Repeated short squeezes are potential threats to the integrity and liquidity of the Treasury market and eventually could drive up the Treasury's borrowing costs. Can the Treasury undertake credible measures to prevent and alleviate short squeezes? Are alternative auction formats more or less susceptible to short squeezes?

One possible way to alleviate short squeezes is to reopen the squeezed security through an auction to provide additional supply. However, it is often difficult to differentiate between specials developing from deliberate manipulation and those developing due to the dealers' misjudging demands in the when-issued market or other phenomenon, such as the dealers' selling the off-the-run security and rolling into the when-issued market (going long) for the soon-to-be on-the-run security.[15] An additional problem with reopening is that, with a commitment to reopen, the future supply of Treasury securities is essentially an uncertain quantity and poses a source of risk to bidders in formulating their bidding strategies. If bidders are risk averse, a risk premium can appear, resulting in higher average auction yields and higher borrowing costs for the Treasury. Other specific measures that have been suggested to increase the supply of squeezed securities include selling these securities directly through the New York Fed's open market desk or facilitating "synthetic reopenings" by lifting certain restrictions on reconstituting the coupon-bearing security through Treasury Separate Trading of Registered Interest and Principal (STRIPs) (whenever applicable).

The preauction when-issued market and the postauction secondary market are integral parts of the entire auction process and may affect the analysis of possible collusion under uniform and discriminatory auctions.

Chari and Weber (1992) argue that bidders' incentive to substantially affect the price they pay by submitting low-enough yield bids (high-enough prices) is less in uniform-price auctions because the yield that bidders are awarded is the stop-out yield, which could often be higher than the yield that they had bid for. Chari and Weber overlook the fact that bidders in uniform-price auctions can increase the quantity awarded to them by tendering low-enough yields. Provided there are other bidders (who may be part of a cartel) whose bids would make the auction clear at higher yields, the aggressive bidders end up cornering a substantial fraction of the uniform-price issue, acquired at lower prices than their bid prices. However, bidders who attempt to corner a discriminatory auction by bidding low-enough yields will have to pay high-enough prices for such bids. Thus, from this perspective the incentive to submit low-enough yields and corner the market may actually be higher in uniform-price auctions than in discriminatory auctions.

In contrast, Nyborg and Sundaresan (1996) argue that short squeezes are more likely to develop under discriminatory auctions if some traders are better informed

13. Anecdotal evidence suggests that they do, but there is no formal documentation.

14. The experiments, however, do not take into account the when-issued and secondary markets.

15. In one case a short squeeze had developed in the thirty-year bond (maturing February 2016) surrounding the auction of the on-the-run thirty-year bond in May 1986; dealers had sold short the seasoned bond to take positions in the May 2016 bond, and suddenly there was a dearth of the seasoned thirty-year bond.

about the value of the to-be-auctioned security than others. Theoretical models of securities markets that take into account such asymmetry of information predict that periods of higher information dissemination are also periods of higher volatility. Nyborg and Sundaresan (1996) find that when-issued yields in a discriminatory auction display increasing volatility through time on the day of the auction while under a uniform-price auction the when-issued yields display decreasing volatility. As a result, the authors conclude that to the extent the existence of higher preauction information helps bidders to structure their bids better bidders face a lower probability of being squeezed by others who submit unanticipated low yields.[16] However, the documented differences in temporal patterns of volatility across the two auction formats are also consistent with the predictions of Wang and Vishwanathan's (1996) model, in which all bidders are equally informed about the value of the Treasury security and the differences in volatility patterns are due to differences in hedging behavior across auction formats; this result calls into question Nyborg and Sundaresan's interpretation.

Repeated short squeezes are potential threats to the integrity and liquidity of the Treasury market and eventually could drive up the Treasury's borrowing costs.

Empirical Evidence

Theoretical models, while insightful, cannot model the auction market in its full complexity. Assumptions often have to be made to keep a model tractable. Therefore, theoretical predictions regarding revenue superiority and susceptibility to short squeezes of alternative auction formats are subject to question unless confirmed by empirical research. Empirical research on Treasury auctions has looked at evidence regarding the existence of the winner's curse, has compared alternative auction formats in terms of their potential savings to the Treasury, and has explored the possible existence of collusion in auctions.

In terms of the winner's curse, Cammack (1991) and Spindt and Stolz (1992) find that it is cheaper to buy three-month Treasury bills in auctions than in the postauction and preauction secondary markets, respectively. The difference in yields is on the order of 1½ to 3 and 4 basis points. Assuming that the secondary market reflects the true value of the security, the authors conclude that bidders do shade their bids in auctions, a consequence of the winner's curse. Although informative, the comparison of the auction yields and the secondary market yields are not direct comparisons because the secondary market securities are quoted for a different delivery day than the auctioned securities. A better approach is to compare the auction yields with the when-issued yields that are for delivery on the same business day. Using proprietary when-issued data from competitive dealers, Simon (1994) and Nyborg and Sunderasan (1996) find that the markup of the average (quantity-weighted) auction yield over the contemporaneous when-issued bid yield (bid-side yield represents the rate that one can lock in to sell) for bills and notes tends to be less than a basis point. Given the possibility of errors in measuring these yields, however, it is not clear that there is any significant economic difference between the two yields and therefore any convincing evidence of winner's curse. Also, for Treasury bills the markup comparisons are compounded by the fact that the required minimum difference between any two yields, often called the tick size of the security, is different in auctions and the when-issued market, as noted by Cohen and McBeth (1994).

Nyborg and Sundaresan (1996) compare the markups in uniform-price and discriminatory formats to investigate whether the switch to the uniform-price format in two- and five-year notes has resulted in higher revenues for the Treasury. They find that the differences in the markups of the average auction yield over contemporaneous when-issued yields (a measure of the Treasury's possible savings) between the two formats depend on the time of the day the when-issued yield is quoted and the maturity of the note. In short, no definite conclusion can be reached regarding the revenue superiority of the uniform-price auction over the discriminatory auction by comparing these markups.[17] However, the data set used is relatively small, and, furthermore, the comparison between the two formats is not entirely controlled because the two- and five-year uniform-price auctions were held at different times and hence in a different interest rate environment than the discriminatory auctions. Given these conditions, small differences in markups would be difficult to identify.

In terms of foreign auction markets, Tenorio (1993) finds that average revenues to the Zambian Treasury decreased after a switch from the uniform-price to the discriminatory format due to lower bidder participation, a result consistent with the assertions of Friedman (1960). Similarly, Umlauf (1993), in a study of bidding in Mexican Treasury auctions, finds that bidder profits, as measured by the difference between quantity-weighted average auction yield and yield in the immediate postauction secondary market, dropped substantially after the Mexican Treasury switched from the discrimi-

natory to the uniform-price format. However, collusion among bidders in the Mexican Treasury auctions is often thought to be a distinct possibility (Back and Zender 1993; Wang and Vishwanathan 1996), and caution is warranted in extrapolating this conclusion to U.S. Treasury auctions.

From a somewhat different perspective, Gordy (1996) examines discriminatory Treasury auctions in Portugal and finds that the use of multiple bids per bidder and the dispersion in the bids of each bidder increase with the volatility of the interest rates. Since the possibility of the winner's curse increases with the uncertainty (volatility) of the value of the underlying object, this evidence can be interpreted as suggesting that the use of multiple bids in Treasury auctions acts as a natural hedge against the winner's curse. The increased dispersion of bids in Swedish discriminatory auctions as well has been found by Nyborg, Rydqvist, and Sundaresan (1997).

Alternative Auction Formats

Currently a few approaches are being contemplated to change the format of auctions. One of these is whether the Treasury should switch to an ascending-price open-outcry auction. Another is whether the Federal Reserve should preannounce its noncompetitive bids. It is insightful to examine these alternatives in light of the research that has been discussed.

Ascending-Price Open-Outcry Auctions. Extant empirical evidence indicates that there is no significant difference in the Treasury's financing cost from selling Treasury securities under either the uniform-price or discriminatory format. One common feature of these two formats is that they are sealed-bid auctions. As the auction procedure becomes more automated, it may be possible to hold electronic open-outcry auctions. In an electronic open-outcry Treasury auction, bidders located in diverse geographical regions of the country would have access to a central computer at the Treasury and would enter bids into their terminals. In fact, the *Joint Report* (U.S. Treasury 1992) suggests that the Treasury consider experimenting with an ascending-price/descending-yield electronic open-outcry auction.

A descending-yield auction would start with the Treasury announcing a yield, perhaps the contemporary yield in the when-issued market or marginally higher, for the opening round with bidders submitting bids at the particular yield. After receiving the bids, the total amount of bids would be announced publicly. The expectation is that the high yield available at the opening round would lead to oversubscription. Thereafter, the auctioneer would decrease the yield at each round gradually until the volume bid is less than the available supply. The bidders who remain until the last round would get the securities at the next-highest yield (that is, the yield of the previous round) while the bidders who dropped out at the next-to-last round would be awarded prorated quantities at that round's yield. In this way, the auction would get cleared at a single yield.

The open format seems to offer several positive features. It allows for the release of more information through the bidding process as the bidders learn the total volume at each yield and possibly the bids of other bidders. The release of more information is favorable from a winner's curse point of view to the extent that access to the additional information attenuates the winner's curse. The availability of more information could also increase bidder participation, thereby making the auction more competitive. In addition, the open-outcry format could be favorable from the perspective of a short squeeze if the auction is structured such that the individual bids at the time they are entered are public knowledge. Bidders would be able to gauge the extent of demand at low yields and revise their bids. For example, those short in the when-issued market would have the option of matching any abnormally high quantities at low-yield bids (as and when they show up) and could avoid being cornered, an option not feasible under the sealed-bid format.

However, there are a few issues about ascending-price Treasury auctions that deserve further study by the Treasury. In particular, the ascending-price/descending-yield format could encourage a type of collusion as follows. If every bidder is part of a cartel and the cartel bids conservatively enough that the net demand is less than the available supply at the first or second round, then the auction would get cleared at the high yields of the initial rounds without providing the Treasury the opportunity to test demand at the lower yields. Is this type of collusion sustainable? If a particular bidder defects from this cartel and bids a much higher quantity at the initial round, then the rest of the cartel members would bid higher quantities at the successive rounds and drive the auction yield successively lower (and prices higher) such that it eventually becomes unprofitable for the defector to get any quantity at the very low market-clearing yield. Realizing ex ante the cartel's response to

16. *Some supporting evidence is documented in Bikhchandani and Huang (1992), who find that in a majority of the bill auctions in their data set at least one yield in the auction was lower than the corresponding when-issued ask yield.*
17. *Wang and Vishwanathan (1996) question the validity of comparing markups across different auction formats because their model predicts that prices in uniform-price auctions are much more variable than in discriminatory auctions, thus introducing more noise in the uniform-price markups.*

defection, no cartel member would possibly defect, and the auction could get cleared at the very initial rounds. However, the Treasury may be able to deter this type of collusion either by specifying a minimum number of rounds or the minimum quantity that each bidder has to tender at each round or at least during the first few rounds. Another type of manipulation could take place in the when-issued market itself if the Treasury were to precommit to starting the auction with a yield that is always either somewhat higher or lower than the contemporary when-issued yield and perfectly predictable by the bidders. In such a case, it is possible that the when-issued yield could be collectively manipulated to be much higher than it would be otherwise and the auction would clear at a much higher average yield even with multiple rounds, costing the Treasury revenue. To avoid this type of potential manipulation, the Treasury could avoid precommitting to any opening yield. Instead the Treasury could choose the opening yield with the addition of a random component—for example, by making it a little higher or little lower than the when-issued yield in a way that is not predictable.

Empirically . . . there seems to be no discernible difference between discriminatory and uniform-price auctions in terms of revenue to the Treasury.

Even with these potential vulnerabilities, the open-outcry auction descending-yield/ascending-price format remains a promising alternative. It allows for greater information dissemination and, with a few extra features added to the contemplated design, perhaps could deter collusion.

Preannouncement of Noncompetitive Bids. Bikhchandani and Huang (1993) suggest that the Federal Reserve should disclose the amount of securities it will tender as noncompetitive bids on behalf of foreign central banks. The Federal Reserve's tender normally constitutes a nontrivial part of the pool of noncompetitive bids. Imperfectly predictable noncompetitive bids are a source of uncertainty to competitive bidders, and decreasing such uncertainty through the Federal Reserve's disclosure might tend to diminish winner's curse and increase auction revenue. One potential disadvantage of such disclosures in uniform-price auctions is that hiding noncompetitive bids could be a deterrent to the type of self-enforcing collusion that arises through the submission of steep demand curves in such auctions. It is possible, however, that the disclosures by the Federal Reserve about the intent of its noncompetitive bids could be beneficial to the Treasury in discriminatory auctions.

Conclusion

The U.S. Treasury is currently experimenting with a uniform-price format for auctioning two- and five-year Treasury notes. All other Treasury securities are still auctioned through the discriminatory format. This experiment was begun with the notion that the attenuation of the winner's curse in uniform-price auctions would lead to increased auction revenues. However, current theoretical research shows that the ability to submit demand schedules in Treasury auctions conveys a strategic advantage to bidders under the uniform-price format. As a result the reduction in winner's curse in uniform-price auctions could be outweighed by the bidders' submitting steep demand schedules that beget a self-enforcing collusion and cause the Treasury's financing cost to actually increase in such auctions. The strategic advantage of demand schedules declines as the level of noncompetitive demand and the number of competitive bidders rise. The existence of preauction and postauction trading in Treasury securities dilutes the strategic advantage that bidders have in uniform-price auctions.

Empirically, however, there seems to be no discernible difference between discriminatory and uniform-price auctions in terms of revenue to the Treasury. While this result may indicate that the theoretical models are too stylized, it may also be the case that it is a little too early to draw any robust conclusion; the data sets used in the empirical tests do not span a sufficiently long time period, and the comparison between the two auction formats is not entirely controlled to account for the different time periods and hence the different interest rate environments in which these auctions were held.

The proposal to switch to electronic ascending-price open-outcry auctions with an implied uniform price may be more important than just switching to a uniform-price auction. Although collusive behavior may emerge in ascending-price auctions and the when-issued market may be manipulated to have an auction clear at a high yield, this article has pointed to some safeguards that the Treasury could adopt to preempt such collusion. These take the form of imposing a lower bound on the amount that competitive bidders need to bid, at least during the early rounds of these auctions, and the Treasury's not precommitting to any opening yield that is predictably related to the contemporary when-issued yield.

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