There's More than One Way To Sell a Security: The Treasury's Auction Experiment

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To finance a deficit of over $200 billion and to refinance maturing debt, the U.S. government sold more than $2 trillion of Treasury securities in 1994 at regularly scheduled auctions. The ability of the government to continue to borrow in this way depends on there being a well-functioning market for government securities. Such a market benefits the taxpayers by lowering the government's borrowing cost. In addition, it provides a convenient way for the Federal Reserve to implement monetary policy. The health of the Treasury security market depends on participants' perception that it isn't subject to manipulation.

However, the integrity of the Treasury securities auction market was called into question when Salomon Brothers, Inc., admitted in August 1991 to serious violations of the auction rules during 1990 and 1991. This led to Congressional hearings and a review of the market by the Treasury, Federal Reserve System, and the Securities and Exchange Commission.[1] Following one of their recommenda-

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[1]See *The Activities of Salomon Brothers, Inc., in Treasury Bond Auctions, Hearings Before the Subcommittee on Securities of the Committee on Banking, Housing, and Urban Affairs, U.S. Senate*, (September 11-12, 1991), and *Joint Report on the Government Securities Market*, Department of the Treasury, Securities and Exchange Commission, Board of Governors of the Federal Reserve System (January 1992).

tions, in September 1992, the Treasury began selling two-year and five-year Treasury notes using a *uniform-price* auction, in which all winning bidders pay the same price, rather than a *discriminatory-price* auction, in which winning bidders pay what they bid.

The choice of auction format is important, since the format can affect the amount of revenue the government will raise in an auction and, therefore, the government's borrowing costs. In its announcement on September 3, 1992, the Treasury stated that it would consider the uniform-price auction a success if "it reduces the U.S. government's finance costs, whether by encouraging more aggressive bidding by auction participants or by attracting more bidders to the auctions."[2] Auction theory provides a basis for determining which format to use and provides a rationale for the experiment. Yet the theory is based on simple models, and the world is not a simple place. Thus, empirical analysis is needed to ultimately determine which format is better. While analyses of the data from previous experiments both in the United States and abroad are inconclusive, most favor the uniform-price auction. Since the current experiment is quite young, it, too, has not yet produced conclusive evidence, but the results thus far do support continuing the experiment so that more data can be collected.

HOW TREASURY SECURITIES ARE SOLD

Auctions have been used to sell Treasury bills (that is, Treasury securities with maturities of a year or less) since they were introduced in 1929. But auctions are not the only way the Treasury could issue its debt. Until the early 1970s, the Treasury sold notes and bonds (which have maturities of more than a year), using methods that set the price before the sale of the securities.[3] But increased volatility of interest rates made such methods risky for the seller and for buyers. So the Treasury began using a modified auction method for notes and bonds in 1970 and a more standard auction method in 1974.

The Primary Market. The Treasury sells securities at regularly scheduled auctions, which constitute the primary market: 13- and 26-week bills are sold weekly, one-year bills are sold every four weeks, two- and five-year notes are sold monthly, three-year and 10-year bonds are typically sold at the quarterly refinancings, and 30-year bonds are sold semi-annually. The gross amount issued has grown through time and was over $2 trillion in 1994 (Figure 1). About one week prior to the auction, the Treasury announces the dollar amount of the particular security it wishes to sell at the auction and invites tenders (sealed bids) for a specified dollar amount of these securities. Bids are due by a specified time on the day of the auction, and the Treasury usually publicizes the results later that afternoon. The securities are then issued to successful bidders within a few days to about a week after the auction.[4]

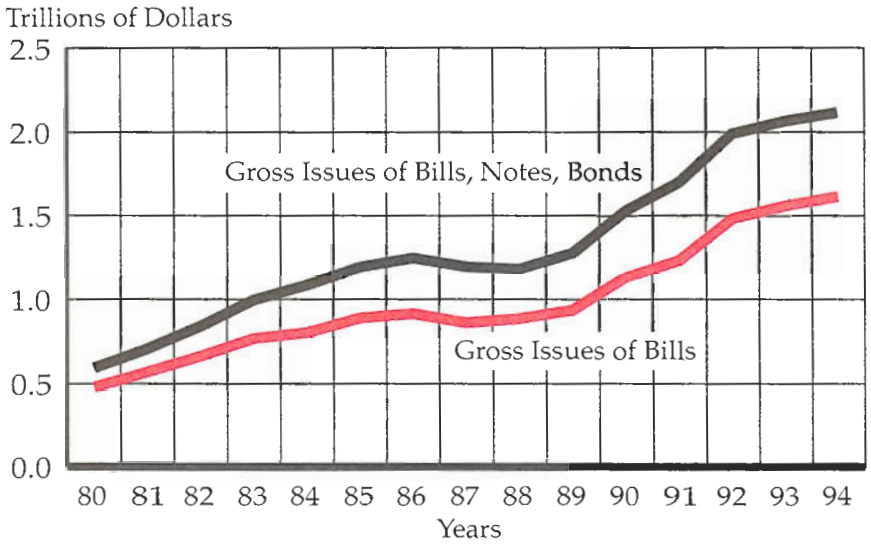
[2]In "Managing the Public Debt," in this *Business Review* (July/August 1994), Keith Sill discusses why the government might want to minimize its interest costs: lower costs mean lower taxes, and if taxes are distortionary to economic activity, then lower taxes provide an economic benefit.

[3]Appendix A of the *Joint Report on the Government Securities Market*, Department of the Treasury, Securities and Exchange Commission, Board of Governors of the Federal Reserve System (January 1992) provides an excellent overview of the history and current operation of the government securities market, and is the source of much of the information in this section. See also James F. Tucker, *Buying Treasury Securities at Federal Reserve Banks* (Federal Reserve Bank of Richmond, October 1993) and Loretta J. Mester, "Going, Going, Gone: Setting Prices with Auctions," this *Business Review* (March/April 1988), pp. 3-13.

[4]For 13- and 26-week bills, the Treasury announces the weekly offerings on Tuesday, auctions the bills on the following Monday, and issues the bills on the Thursday following the auction. For 52-week bills, it announces on a Friday, auctions on the following Thursday, and issues

FIGURE 1

Gross Issues of Marketable Treasury Securities



Source: U.S. Department of Treasury, Office of Market Finance

Two different types of bids can be submitted in Treasury auctions: competitive and noncompetitive.[5] The awards to competitive bidders account for the larger percent of total awards: they average about 80 percent of bill auction awards to private investors and over 90 percent of note and bond awards, despite the fact that, on average, only about 75 to 85 bidders submit competitive bids, while there are nearly 20,000 noncompetitive bidders per auction. Money market banks, dealers, and other institutional investors who purchase large quantities of securities typically submit competitive bids. These tenders indicate the amount of the security they want to purchase and the price they are willing to pay. This price is stated in terms of the yield (or the discount rate for bills) that investors are willing to accept for investing in the security: higher yields mean lower prices paid by the investor, and hence, higher borrowing costs to the Treasury. Competitive bidders are permitted to submit more than one bid, but no single bidder is allowed to win more than 35 percent of the total amount of the security being sold.[6] This rule is intended to prevent any bidder from cornering the market in a particular security.

on the Thursday following the auction. For two- and five-year notes, it usually announces on a Wednesday in mid-month, auctions a week later, and issues on the last day of the month. For three- and 10-year notes, it usually announces on the last Wednesday of January, April, July, and October, auctions during the first full week of February, May, August, and November, and issues on the 15th of the auction month. Auctions of 30-year bonds follow the same schedule but are offered just twice a year, in January and July. (See Tucker, p. 25.) The Treasury stopped selling seven-year notes after April 1993; prior to this the Treasury offered them quarterly with the three- and 10-year notes.

The minimum denominations sold are $10,000 for bills; $5000 for two- and three-year notes; and $1000 for other notes and bonds. Securities are sold in $1000 increments above the minimum denominations. (See Tucker, pp. 11 & 17).

[5]Bids can be submitted at Federal Reserve Banks and most of their branches and at the Treasury's Bureau of the Public Debt. Competitive bids are usually due by 1 pm on the day of the auction and noncompetitive bids by noon—these two types of bids are described in the text below. In addition to private bidders, the Federal Reserve also buys securities at the auctions to replace maturing issues in its own account and on behalf of foreign governments. The Fed is treated as a noncompetitive bidder.

[6]While a single bidder can submit bids for more than 35 percent of the offering at one yield, the Treasury does not recognize the excess. See p. A-5 of the *Joint Report*.

A significant group of competitive bidders in Treasury auctions are the so-called primary government securities dealers. Currently there are 39 such dealers, whose role is to ensure that there is wide participation in the Treasury security auctions. They purchase large amounts of Treasury securities in the auctions for their own accounts, and they also purchase securities for their customers. The Federal Reserve buys and sells securities from these dealers in conducting monetary policy. In general, these dealers account for over two-thirds of awards over $1 million. But they typically do not hold the securities they have purchased; often they have made arrangements prior to the auction to sell the securities they will win. (See the discussion of the when-issued market below.)

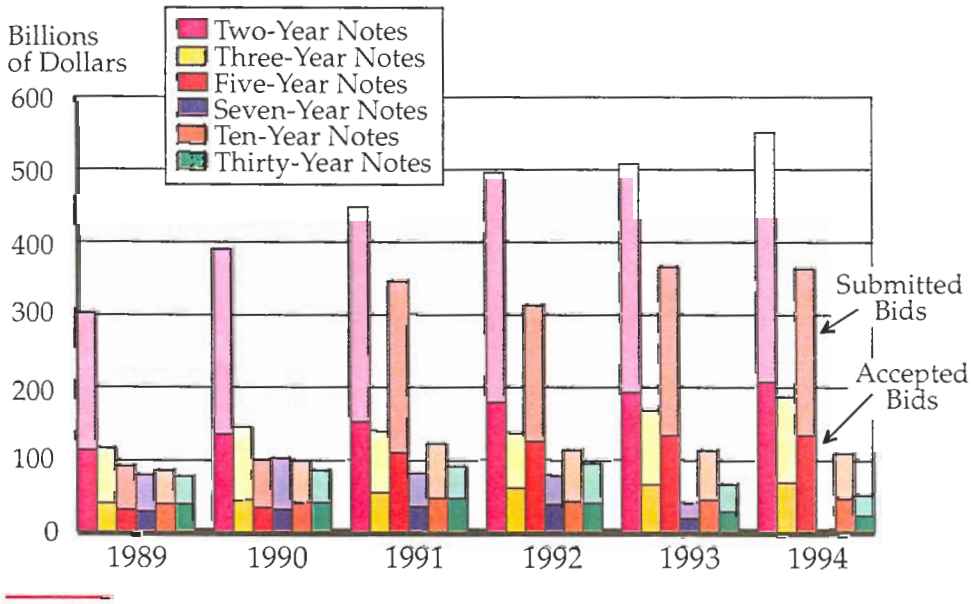
The other type of bids in Treasury auctions, noncompetitive bids, are made by smaller or less experienced investors. By placing a noncompetitive bid, the bidder is assured of winning the amount that he indicated on his tender, up to the $1 million limit placed on such bids for bills and the $5 million limit placed on such bids for notes and bonds. The tender does not indicate the price, since a noncompetitive bidder agrees to pay the quantity-weighted average of the accepted competitive bid prices.

Until the current auction experiment, the Treasury had relied on *discriminatory-price* auctions to determine the winners and the prices they paid in all of its security auctions, and it continues to use this method for securities other than the two-year and five-year notes.[7] Once the bids are in, the Treasury sets aside the amount of securities requested by the noncompetitive bidders. The remainder is allocated to the competitive bidders, beginning with those who bid the highest price (that is, lowest yield) and then working down, until the total amount is issued. A winning competitive bidder pays a price equal to what he bid, which is what makes this a discriminatory-price auction. During the past five years, about 35 to 45 percent of the dollar volume of bids submitted in each auction by private investors were accepted, that is, won securities, with the higher percentage occurring in auctions of longer maturities, since there is a lower volume of bids in these auctions (Figure 2).

[7]The Treasury also experimented with a uniform-price bond auction from 1973-76.

FIGURE 2

Total Volume of Submitted & Accepted Bids (excluding Federal Reserve tenders)



Source: Treasury Bulletin, U.S. Department of Treasury, various issues

This primary auction market does not stand in isolation. Other related markets can affect the strategies bidders use in the primary auction market.

The When-Issued Market. Even though the auction market is called the primary market for Treasury securities, it isn't the first place a particular security is bought or sold. In fact, between the time the auction of a particular security is announced until the time the security is issued, traders can buy or sell that security in a forward market called the when-issued market.[8] In this market, sellers contract to deliver a particular security on its issue date at a certain price. Notice that such trading can (and does) occur before the auction, and so occurs before sellers know whether they have won the security in the auction and before they know the winning prices. Unlike competitive bidders in the auction, the buyers in this market know the amount of the security they will receive on the issue date and the price they will have to pay.[9]

The existence of when-issued trading can affect the strategies bidders use in the auctions because it affects bidders' positions as they go into the auction: bidders who have bought the security in the when-issued market before the auction go into the auction with long positions (that is, they already own some of the securities) and bidders who have sold the security in the when-issued market go into the auction with short positions. Another reason the when-issued market can affect bidders' strategies is that it serves a "price discovery" role. By participating in this market and seeing the prices at which trades are being made, traders gain information on the strength of demand for an issue and on the disparity of participants' views about the issue, which can be useful when they prepare their own bids. On the other hand, participants who feel they have some very valuable private information concerning the value of the issue (for example, they have what they believe is a more accurate forecast of interest rate changes) might refrain from trading in this market so that they can keep the information private and use it in preparing their bids.

The Secondary Market. Once a Treasury security is issued it can be traded in a secondary market. This market is mainly an over-the-counter market in which dealers, brokers, and other investors make trades over the phone; the most active trading is in the most recently issued securities. The existence of the secondary market also affects the strategies bidders use in the auction. In fact, it can affect the choice of participating in the auction in the first place, since it provides another place in which to purchase the security.[10]

THE AUCTION EXPERIMENT AND ITS RATIONALE

One of the Treasury's aims is to maximize the revenue it receives or, what is the same

[8]For example, the weekly auction of 13-week Treasury bills is announced on Tuesday; the auction is held the following Monday, and the bills are issued on Thursday. So the when-issued market for this bill runs from Tuesday to Thursday of the following week.

[9]For further discussion of the when-issued market, see Suresh Sundaresan, "An Empirical Analysis of U.S. Treasury Auctions: Implications for Auction and Term Structure Theories," First Boston Working Paper Series, FB-92-37, Graduate School of Business, Columbia University (November 1992); and Kjell G. Nyborg and Suresh Sundaresan, "Discriminatory Versus Uniform Treasury Auctions: Evidence from When-Issued Transactions," mimeo (October 1994).

[10]Another important market in which Treasury securities are traded is the repo market. Dealers are able to buy or sell Treasury securities for short-term periods (usually overnight) using repurchase agreements ("repos"). A repo seller provides securities in exchange for funds and agrees to repurchase the securities at the price and date specified in the repo contract. The market can be used to finance securities' positions, to obtain securities temporarily to complete other transactions, or to invest idle cash balances. (See *Joint Report*, pp. A11-A12.)

thing, lower its borrowing cost. But it isn't enough to consider which auction format will maximize revenue from a single auction—selling securities isn't a one-shot game; the Treasury has to determine the long-run implications from using a particular format. While one format might lead to more revenue than another when a single auction is considered, if the format is more vulnerable to manipulation by a single bidder or collusion by a group of bidders, it may lead to decreased participation in future auctions, which has negative implications for revenue over the long run. If participants feel the auction is unfair or that more informed bidders can take advantage of less informed bidders (perhaps by colluding), the demand for securities in the auction may decline. Uninformed bidders might decide to wait to purchase the securities they need in the secondary market, which would mean less revenue for the government. Similarly, if one type of format is more vulnerable to collusion, it, too, might not be the best choice, even if in the absence of collusion it might be the type of auction that maximizes the government's revenues.

In September 1992, the Treasury announced that it would conduct a uniform-price auction experiment, including all auctions of two- and five-year notes from September 1992 through August 1993. The experiment has been extended twice, the second time on August 3, 1994, for all two- and five-year notes indefinitely. In the uniform-price auction, the winners are determined in the same way as in the discriminatory-price auction, but instead of paying the price they bid, all winners pay the same price, which is the highest rejected bid (or what is the same thing for Treasury auctions, the lowest accepted bid).[11,12]

On the face of it then, it would seem that the Treasury would make more revenue from selling its securities via a discriminatory-price auction, since those submitting higher bids would pay the amount they bid for a security, while in a uniform-price auction they would pay less. But the auction format can also affect demand for securities; if uniform-price auctions increase demand, this may more than compensate for the loss of revenue due to a single price. And as discussed above, some auction formats are more susceptible to manipulation or collusion than others, which can directly affect revenue and indirectly affect demand and, therefore, revenue.

Some Simple Auction Theory. Arguments in favor of the uniform-price auction for Treasury securities are based on what has been learned from economic models of auctions.[13] Economists model an auction as a game with bidders playing against each other. The object of the game is to win the object being auctioned at the lowest possible price, and each bidder devises a strategy with this in mind. A bidder's strategy will depend on what information the bidder has. Some information will be available to all bidders (for example, the Treasury an-

[11]In Treasury auctions these two prices are the same, since there is always excess demand for Treasury securities at the lowest accepted bid.

[12]This was not the first time a uniform-price auction had been recommended or used in U.S. financial markets. In 1960, Milton Friedman, who later won the Nobel Prize in economics, recommended that the Treasury switch to a uniform-price auction to sell Treasury bills; others disputed his recommendation. In six auctions between January 1973 and May 1974, the Treasury sold long-term bonds this way. In the wake of the Salomon Brothers scandal, Friedman reiterated his recommendation for the uniform-price auction (see *Wall Street Journal*, August 28, 1991, p. A8).

[13]Most of the models have focused on the auctioning of a single object. For nontechnical discussions of auction theory see Mester (1988); Paul Milgrom, "Auctions and Bidding: A Primer," *Journal of Economic Perspectives*, 3 (Summer 1989), pp. 3-22; Sushil Bikhchandani and Chi-fu Huang, "The Economics of Treasury Securities Markets," *Journal of Economic Perspectives*, 7 (Summer 1993), pp. 117-34; John McMillan, "Selling Spectrum Rights," *Journal of Economic Perspectives*, 8 (Summer 1994), pp. 145-62.

nounces the auction date and size of the issue before each auction, and the auction rules are known to all), but other information is privately held by each bidder. The assumptions made in theoretical models about the nature of bidders' private information range along a broad spectrum. At one end of the spectrum, models assume each bidder knows for certain how she values the object and that this information is totally private, reflecting her individual taste for the object—this is called a *private values auction.* At the other end, models assume that the object is worth the same to all bidders but that they are unsure of this value—this is called a *common values auction.* A bidder's private information might tell her something about the true market value of the object, although not enough to be certain. At the time of bidding, no bidder knows the market value for sure and each makes an estimate of this value based on her private information.

Treasury auctions are more like common values auctions than private values auctions, since the value of the security is largely determined by its value in the secondary market. A bidder in a common values model would like to discover the private information of other bidders not only because it would tell her something about how those other bidders are likely to bid, but also because it would reveal something more about the likely market value of the object, which is what each bidder is trying to estimate. Also, the bidder's profit is determined by her private information—if all information is public, then the winner will not earn any profit in the auction; the rewards to bidding in a common values auction depend on the value of the bidder's private information.

Common values auctions are subject to the "winner's curse," which affects bidders' strategies and therefore the revenue that a seller, like the Treasury, can expect to receive in the auction. Each bidder is unsure of, but forms some estimate about what the object being sold is worth; in Treasury security auctions it would be the price of the security in the secondary market. If she bids her estimate and wins, this tells her that everyone else thinks the object is worth less than she did. On average, the winner who bids her estimate will pay more than the object is worth on the open market. Hence, winning is a curse! To avoid the curse, each bidder should shade her bid down from what she thinks the object is worth. But shading the bid below her estimate can affect the bidder's probability of winning. Hence, the amount a bidder shades from her estimate depends on how many other bidders there are and also how the bidder feels about the risk of losing. When there are fewer bidders, a bidder can shade down her bid more without affecting her probability of winning, because there is less chance that someone else's bid lies just below hers. If a bidder is risk-averse, she will care very much about the risk of losing the object and will shade down her bid less than if she were risk-neutral, as a kind of insurance against losing: a risk-averse bidder is willing to pay more to avoid the loss from losing. The amount of bid shading is also affected by the degree of information differences across bidders.

The winner's curse also gives bidders the incentive to gather more information about the value of the object being sold. As explained above, in Treasury auctions this information can be garnered in the when-issued market. Hence, when the winner's curse is severe, it is likely that there will be more trading in the when-issued market. It also means that bidders have more incentive to pool their bids, since this helps them get a better estimate of the common value, and the use of dealers who pool bids and place large orders will be higher.[14]

Rationale for the Experiment. One ration-

[14]See Vincent Reinhart, "An Analysis of Potential Treasury Auction Techniques," *Federal Reserve Bulletin*, 78 (June 1992), pp. 403-13.

ale for switching to a uniform-price auction from a discriminatory-price auction is that, when bidders are risk-neutral, the uniform-price auction is less susceptible to the winner's curse. In a discriminatory-price auction, a risk-neutral bidder will tend to shade down her bid more than in a uniform-price auction because her bid is also what she pays when she wins; if other bidders estimate the value to be much lower than she does, the winning bidder will be paying much too high a price. In a uniform-price auction, on the other hand, the winning bidder need not be too worried about paying way too much; she can bid high to improve her chance of winning, but she doesn't have to pay this high price. (Recall, she only has to pay the lowest accepted bid.) In other words, bidders bid more aggressively in the uniform-price auction than in the discriminatory-price auction. In fact, when bidders are risk-neutral and only one object is being sold, the price paid by the winner in a uniform-price auction is higher on average than the price paid by the winner in a discriminatory-price auction. This theoretical result for auctions of single objects plays a large role in arguments made for switching to uniform-price Treasury auctions, despite the fact that in Treasury auctions more than one object is being sold.

The other line of argument for changing auction formats is based on the potential for manipulation or collusion afforded by different auction techniques, which can affect auction revenues. Collusion is bad from the seller's viewpoint if it involves bidders' conspiring to keep prices down. Several economists have argued that collusion might be more difficult in the uniform-price auction than in the discriminatory-price auction. They argue that because the winner's curse is less severe in the uniform-price auction, less informed bidders will be less disadvantaged, which should encourage participation. Collusion would be more difficult, as the number of bidders would be larger.[15] Either shading down bids to avoid the winner's curse or colluding with others to keep bids down will lead to less revenue for the Treasury. So if the uniform-price format alleviates the winner's curse and makes collusion less likely, it should be the preferred format.

Theory and Practice. But the real world of Treasury-security auctions isn't as simple as the theory discussed above may suggest. First, even in the simple models, if bidders are risk-averse, one can't predict which auction format—uniform-price or discriminatory-price—will yield the higher expected revenue. Although it is likely that most bidders in Treasury auctions are risk-neutral, since any one auction represents a small percentage of their assets, the fact that many come to the auction with a significant short position (from selling in the when-issued market before the auction) can make them act in a risk-averse manner, since losing would be costly if they are unable to obtain the securities they want at a reasonable price in the secondary market.

Second, Treasury auctions are multiple-object auctions in which bidders desire more than one unit of the item being auctioned, but there has been little analysis of these kinds of auctions. As in single-unit auctions, a uniform-price auction of multiple units will yield greater revenue on average than a discriminatory-price auction when each bidder just demands a single unit. But this is not generally true when bidders want to win more than one unit. In auctions where bidders demand multiple units, Kerry Back and Jaime Zender (1993) show that bidders will tend to play strategies in uniform-price auctions that will curtail price competition, and thereby hold down revenue. In some cases this effect will be strong enough so that the discriminatory-price auction will

[15]See Kerry Back and Jaime F. Zender, "Auctions of Divisible Goods: On the Rationale for the Treasury Experiment," *Review of Financial Studies* (Winter 1993), pp. 733-64 and Friedman (1991).

generate more revenue than the uniform-price auction when bidders demand multiple units, even though the opposite occurs in single-unit auctions. (See *Steeper Bids Can Curtail Price Competition in Uniform-Price Multiple-Unit Auctions.*)

A third complication is the impact of the when-issued and secondary markets on bidders' strategies, which has not been well studied. In their theoretical model, Sushil Bikhchandani and Chi-fu Huang (1989) show that accounting for the secondary market can be important in that it can lead bidders to bid more aggressively in uniform-price auctions to indicate to secondary-market participants that the securities are valuable. This suggests that for Treasury auctions, the uniform-price auction might generate more revenue for the Treasury.[16]

Finally, the argument that uniform-price auctions are less susceptible to collusion or manipulation than discriminatory-price auctions doesn't seem that strong. It's hard to believe that the *competitive* bidders in a Treasury auction are uninformed—under either auction format, the uninformed bidders are better off placing noncompetitive bids (see Bikhchandani and Huang, 1993). And in either format, collusion among a group of bidders would be hard to sustain, since one of the group could deviate from the agreed upon price, bid a slightly higher amount, and win a large share of the amount auctioned (subject to the quantity limits set by the Treasury). In fact, Bikhchandani and Huang (1993) have argued that it might even be easier to sustain collusion in uniform-price auctions than in discriminatory-price auctions.[17]

Manipulation by a single bidder is more likely to be a potential problem than collusion by a group of bidders. So long as there are those who need securities but do not bid in the auction and so must purchase in the secondary market, there is the potential for manipulation. A well-capitalized bidder might try to corner the market in a Treasury issue, and profit by selling to anyone who sold short in the when-issued market and decided to purchase the issue in the secondary market instead of at the auction. While the Treasury might gain in the short term (since to corner the market, the bidder would have to bid high in the auction), if such manipulation is widespread and occurs often, it would tend to drive participants from the market and this would lead to losses for the Treasury in the long term.[18,19] While it is illegal to corner the market, the auction format might have an influence on the ability to (illegally) do so. Bikhchandani and Huang (1993) argue that a uniform-price auction is more vulnerable to

[16]See Sushil Bikhchandani and Chi-fu Huang, "Auctions with Resale Markets: An Exploratory Model of Treasury Bill Markets," *Review of Financial Studies*, 2 (1989), pp. 311-39.

[17]Bikhchandani and Huang (1993) point out that in discriminatory-price auctions, any profitable collusive arrangement involves every bidder agreeing to bid only at low prices. But then deviating and bidding a slightly higher (but still low) price yields a short-term gain. Profitable collusion in the uniform-price auction need not involve all bidders bidding at low prices (since they pay the highest accepted or lowest rejected bid and not what they themselves bid). Therefore, a deviation from the collusive arrangement in a uniform-price auction might involve bidding at a high price; such a deviation would not necessarily be profitable. Hence, the collusive arrangement might be easier to sustain in the uniform-price auction than in a discriminatory-price auction. In other words, discriminatory-price auctions might be less susceptible to collusion.

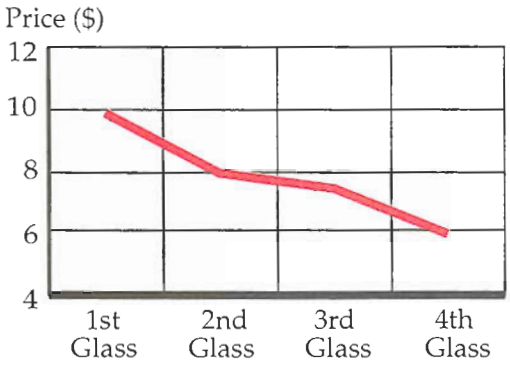
[18]Bikhchandani and Huang (1993) and Reinhart (1992) discuss the potential for manipulation in different auction formats.

[19]In August 1991, Salomon Brothers, Inc., admitted to placing unauthorized bids in some auctions in 1990-91 in an attempt to gain a larger share of the securities being sold. See *Press Release of Salomon Brothers, Inc.*, August 9, 1991; the Joint Report, Appendix C; and "Statement of Salomon, Inc. Submitted in Conjunction with the Testimony of Warren E. Buffett," *Hearings* (1991), pp. 256-312.

Steeper Bids Can Curtail Price Competition in Uniform-Price Multiple-Unit Auctions

How might a discriminatory-price auction of multiple units generate more revenue for the seller than a uniform-price auction, even though in auctions of single items (with risk-neutral bidders) the opposite revenue ranking occurs? Back and Zender (1993) point out that when bidders demand more than one unit, they can play strategies in uniform-price auctions that essentially curtail price competition. The reduced price competition can lead to diminished revenue for the seller, making the discriminatory-price auction a better choice in multiple-unit auctions.

Nick's Initial Bid Schedule



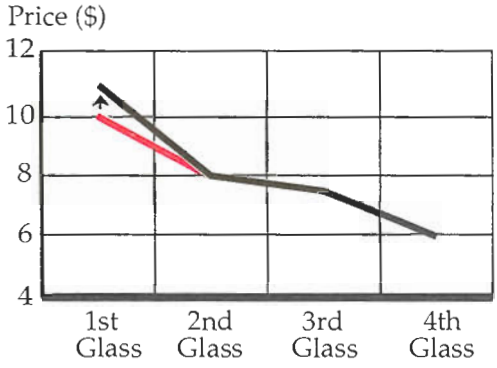
A simple example illustrates this. Suppose there are four martini glasses being sold via a uniform-price auction to two bidders, Nick and Nora, and they both believe that after the auction each glass will be worth $13. Nick and Nora submit bids describing the quantities and prices of the glasses they want to purchase. Suppose Nick submits the following four bids: $10 for one glass, $8 for one glass, $7.50 for one glass, and $6 for one glass, and suppose Nora also submits these bids. The auctioneer will award the glasses starting with the highest bid-price and working down until all four glasses are awarded. So the bids Nick and Nora have submitted essentially describe what each is willing to pay for each additional glass they might win. For example, each knows that the $8 bid won't be accepted unless the $10 bid is accepted, and so on. Given their bids, in a uniform-price auction, Nick and Nora would each receive two glasses, and they would pay $8 per glass (the lowest accepted price).[a] Since they expect the glasses to be worth $13 apiece, each would earn an expected profit of $10 [= 2×($13-$8)] on their winnings.

Now suppose Nora wanted to win all four glasses. To win four, she would have to increase the prices in all four of her bids to $10.01, since she would need to beat Nick's bid of $10 and drive him out of the market. With this new set of bids, Nora's total profit would increase to $11.96 [= 4×($13-$10.01)], so it pays her to change her bids.[b] And the seller would receive $40.04 [= 4×$10.01] in revenues.

But suppose Nick had submitted a steeper schedule of bids. That is, suppose he had bid $11, instead of $10, for one glass and left the rest of his bids the same. Nothing would change in the uniform-price auction; again, Nick and Nora would each receive two glasses and pay $8 per glass. But for Nora to increase her winnings from two to four, she would now have to beat Nick's $11 bid. So she would have to increase the prices in all four of her bids to $11.01. Nora's total profit with her new set of bids would be only $7.96 [= 4×($13-$11.01)], and it would not be profitable for Nora to change her bids.[c] Hence, the seller's revenues would remain $32.

Thus, by submitting steeper bid schedules, bidders can in effect "collude" to keep down the prices they pay. And in a uniform-price auction, such a strategy is costless—Nick did not have to pay the $11 he bid to win the first glass, whereas in the discriminatory-price auction he would have had to.

Nick's New, Steeper Bid Schedule



[a]We use the lowest accepted price as the uniform price instead of the highest rejected price, since that is what is specified in the Treasury experiment. The analysis is similar using the highest rejected price as the uniform price.

[b]This occurs because the value of the two additional glasses is greater than the marginal cost of purchasing the extra glasses. The additional glasses are worth $26 [= 2×$13], and to win four glasses instead of two, Nora would have to pay only an additional $24.04 (= the cost of the two new glasses [= 2×$10.01], plus the extra cost for the first two glasses [= 2×$2.01]).

[c]This occurs because the value of the two additional glasses is now less than the marginal cost of purchasing the extra glasses. The additional glasses are worth $26 [= 2×$13], but to win four glasses instead of two, Nora would have to pay an additional $28.04 (= the cost of the two new glasses [= 2×$11.01], plus the extra cost for the first two glasses [= 2×$3.01]).

manipulation than a discriminatory-price auction, since in the discriminatory-price auction if a bidder bids high to corner the market, he has to pay what he bid. This also means it is more costly in discriminatory-price auctions to build a reputation for aggressive bidding, which can be manipulative.[20]

The divergence between simple auction theory and auction practice means that it is really an empirical question as to which auction format is best; hence, the need for the Treasury's auction experiment. The results will very likely be interesting for theoretical economists as well as the Treasury because the results will suggest which differences between reality and theoretical models are the economically important ones and, therefore, worth further study.

WHAT WE HAVE LEARNED FROM AUCTION EXPERIMENTS

We can look to some previous empirical studies as well as the data gathered so far from the current Treasury experiment to assess the likely impact of switching to the uniform-price auction.[21] Figure 3 helps keep track of the results.

The Treasury's Previous Experiment. Studies that examine the Treasury's previous experiment in the 1970s might give us an idea of what to expect this time (although there have been many innovations and regulatory changes in financial markets since that experiment was run). In an unpublished Treasury Department study, Che Tsao and Anthony Vignola found that in the six single-price auctions out of 16 auctions from January 1973 through August 1976, demand from nondealers increased somewhat, and the authors concluded that the Treasury would have saved about $60 million by using a uniform-price auction for the 10 issues sold via discriminatory-price auctions. This study is often cited by those advocating the uniform-price format, but David Simon (1994a) reports that the authors told him that their results should be viewed as preliminary because of important data problems they subsequently discovered.[22]

Simon's own study re-examined the early experiment and found that the Treasury did better with the discriminatory-price auctions than with the uniform-price auctions. He found the markup of the average accepted rates in the auctions over rates in the when-issued market shortly after the auctions were a statistically significant 7 to 8 basis points higher at uniform-price auctions than at discriminatory-price auctions, holding constant the effects of other factors. This markup measures the premium the Treasury has to pay to issue new debt. The when-issued rate is the rate market participants require to purchase the security; a lower rate means they are willing to pay a higher price. Therefore, the higher the markup, the higher the Treasury's borrowing costs and the higher the profits that go instead to dealers who sell to these market participants after the auction. Simon estimated that the early single-price auctions cost the Treasury about 0.75 percent of the face value of the auctioned securities in lost revenue.

Evidence from Other Countries. Evidence from other countries that switched auction

[20]If one bidder is known to bid aggressively, it can deter others from doing so by making the winner's curse worse—if a bidder beats the aggressive bidder it means he's really paid too much. See Bikhchandani and Huang (1993) for further discussion.

[21]Back and Zender (1993) have a helpful review of some of the empirical studies.

[22]See Che S. Tsao and Anthony J. Vignola, "Price Discrimination and the Demand for Treasury's Long Term Securities," unpublished manuscript, U.S. Department of Treasury (1977); and David P. Simon, "The Treasury's Experiment with Single-Price Auctions in the Mid-1970s: Winner's or Taxpayer's Curse?" *Review of Economics and Statistics*, 76 (November 1994a), pp. 754-60.

FIGURE 3

Empirical-Study Score Card

Study		Results Favor	
		Discriminatory-Price Auction	Uniform-Price Auction
Tsao and Vignola (1977)	16 U.S. Treasury bond auctions, January 1993-August 1976 (data problems subsequently discovered)		×
Simon (1994a)	16 U.S. Treasury bond auctions, January 1993-August 1976	×	
Umlauf (1993)	Mexican Treasury bill auctions, 1986-91		×
Tenorio (1993)	Zambian foreign exchange market auctions, October 1975-January 1987		×
Nyborg and Sundaresan (1994)	U.S. Treasury when-issued market, July 1992-August 1993		×
U.S. Department of Treasury	U.S. Treasury securities, June 1991-May 1994	inconclusive	

formats suggests a different story. Steven Umlauf (1993) studied bidding in Mexican Treasury bill auctions over the period 1986-91.[23] In 1986, the Mexican government began auctioning its Treasury bills using rules similar to the ones used in the United States. In 1990 its Treasury substituted uniform-price auctions for discriminatory-price auctions to try to combat collusion and to increase auction revenues. Umlauf found that before the switch, the six largest bidders, who accounted for very large shares of the auction purchases, were colluding and making profits. But these profits were eliminated after the switch.[24] These results suggest (but don't prove) that there was

[23]He focused on one-month peso-denominated zero-coupon securities called CETES. See Steven R. Umlauf, "An Empirical Study of the Mexican Treasury Bill Auction," *Journal of Financial Economics*, 33 (1993), pp. 313-40.

[24]In the 181 discriminatory-price auctions analyzed, aggregate competitive bidder profits averaged $36,000 per auction, with the six largest bidders earning over 80 percent of total competitive auction profits. But in the 26 uniform-price auctions analyzed, aggregate competitive

collusion in the discriminatory-price auctions but not in the uniform-price auctions, and they favor the uniform-price auction from a revenue standpoint. (Although since only 26 uniform-price auctions are included in the sample and they span only 10 months, it is debatable whether the bidders had enough experience with the new auction to make the results a certainty.)

Rafael Tenorio (1993) analyzed data from foreign exchange market auctions held weekly in Zambia from October 1985 to January 1987.[25] Funds that were auctioned came mainly from export proceeds and from foreign aid. At the start, Zambia used uniform-price auctions, but after authorities became alarmed about what they considered an excessive depreciation of the Zambian currency (Kwacha), the authorities switched to a discriminatory-price format with the 43rd auction. The difference between the supply and demand of currency grew so much that the auctions had to be suspended after the 68th. Tenorio found that uniform-price auctions yielded higher revenues than discriminatory-price auctions because there was greater participation (as measured by the number of bids and the total quantity demanded); had participation been the same in both auctions, his results suggest there would have been no significant difference in revenues. Tenorio also found that it takes a while for bidders to adapt to a new auction format.

The Current U.S. Treasury Experiment. Kjell Nyborg and Suresh Sundaresan (1994) studied the period July 1992 to August 1993 using data on all the transactions in the when-issued market executed by Garban, one of the four most active interdealer brokers in the U.S. Treasury market. They found that for discriminatory-price auctions, the average accepted yield in the auction was higher then the average rate in the when-issued market during the half-hour before the auction, but for uniform-price auctions, there was no difference. This suggests that dealers were shading down their bid prices (and so bidding at higher yields) in discriminatory-price auctions but not in uniform-price auctions, which is consistent with the theoretical result for single-unit auctions that the winner's curse is more severe in discriminatory-price auctions. Hence, the uniform-price auction should produce more revenues for the Treasury.[26]

Nyborg and Sundaresan also show that with uniform-price auctions, when-issued rates were highly volatile before bidding but fluctuated less after the auction, while with discriminatory-price auctions, volatility increased after the auction. This suggests that more information is released in the when-issued market before the auction when the uniform-price format is used than when the discriminatory-price format is used. And it suggests that in discriminatory-price auctions, dealers are bet-

bidder profits averaged -$3000 per auction (essentially zero). And the average profits of the six largest bidders were essentially zero, too. The weighted-average profit margin (that is, the quantity-weighted average spread between the resale price and auction price) was 1.84 basis points for discriminatory-price auctions and -0.3 basis points for uniform auctions. This difference across auction format is statistically significant at the 1 percent level.

[25]See Rafael Tenorio, "Revenue Equivalence and Bidding Behavior in a Multi-Unit Auction Market: An Empirical Analysis," *Review of Economics and Statistics*, 75 (May 1993), pp. 302-14.

[26]For the discriminatory-price auctions of two- and five-year notes, the markup ranged from 0 to 1/2 of a basis point, and was statistically different from zero. For the uniform-price auctions, the markup ranged from -1/2 to 3-1/2 basis points and was not statistically different from zero, since it fluctuated a great deal. The markup's higher volatility in the uniform-price auctions occurs because there are more trades in the when-issued market prior to the auction when the auction format is uniform price than when it is discriminatory price, indicating greater liquidity of the when-issued market when the auction is uniform price. See Nyborg and Sundaresan (1994) for further details.

ter able to trade strategically, masking their private information (that is, knowledge of their customers' orders) prior to the auction and trading on it after the auction, thereby inducing higher volatility in the when-issued rates.[27] The greater level of information released in uniform-price auctions means there is less disparity in information held by bidders, which can lessen the severity of the winner's curse; this might encourage participation and so lead to a higher selling price and, therefore, revenues for the Treasury.

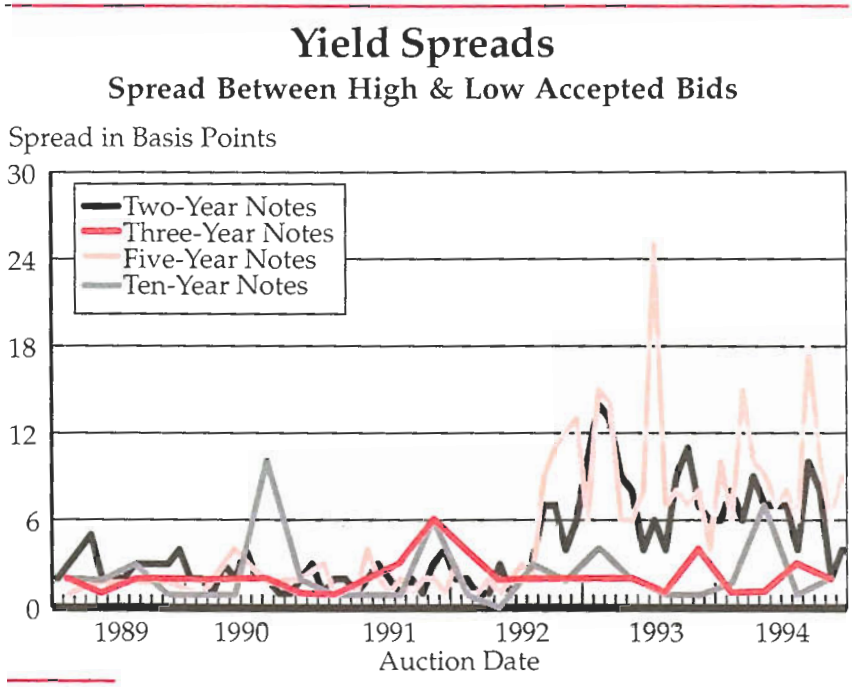
Based on the data collected on the experiment through May 1994, the Treasury Borrowing Advisory Committee, which advises the Treasury on the amount to auction, feels that the uniform-price auction is neutral with respect to Treasury borrowing costs.[28] The data do show that the two- and five-year notes may be more widely distributed under the uniform-price format than under the discriminatory-price format. Broader participation and less concentration suggest less chance of collusion and manipulation. The average share of large competitive awards (based on bids of at least $1 million) to primary dealers in the September 1992 to May 1994 experiment period fell to about 66 to 67 percent of total private awards from about 69 percent in the June 1991 to August 1992 period when discriminatory-price auctions were used; the share to their customers rose to 25 to 26 percent from about 21 percent.[29] (Note, however, that these changes aren't statistically significant.) By contrast, the awards to dealers of three- and 10-year securities rose between the two periods, and awards to their customers of three-year notes were unchanged and of 10-year notes were down about 13 percentage points.[30]

[27]Simon also found evidence of trading on private information in discriminatory-price auctions. See David P. Simon, "Markups, Quantity Risk, and Bidding Strategies at Treasury Coupon Auctions," *Journal of Financial Economics*, 35 (February 1994b), pp. 43-62. But Bikhchandani and Huang (1992) found no evidence of collusion in discriminatory-price auctions of 13- and 26-week Treasury bills from February 1986 through February 1988. See Sushil Bikhchandani and Chi-fu Huang, "The Treasury Bill Auction and the When-Issued Market: Some Evidence," WP #3467-92 Sloan School of Management, MIT (September 1992).

[28]See "Report to the Secretary of the Treasury from the Treasury Borrowing Advisory Committee of the Public Securities Association" (August 3, 1994).

[29]These data are reported in "Charts on the Uniform-Price Experiment," attached to the "Committee Charge," U.S. Department of Treasury (August 2, 1994).

FIGURE 4



Source: *Treasury Bulletin*, U.S. Department of Treasury, various issues

The data also show that transaction volumes in the when-issued market on days of uniform-price auctions have increased notably, suggesting improved liquidity, which can lower borrowing costs. And as auction theory would predict, the spread between the highest and lowest yield of accepted bids has increased in the two- and five-year note auctions since the uniform-price auction has been adopted, while in the three- and 10-year auctions there has been little change (Figure 4).

WHICH FORMAT IS BETTER?

Auction theory cannot yet provide a definitive answer as to whether a discriminatory-price auction or a uniform-price auction would result in lower borrowing costs for the U.S. Treasury. Thus, we must rely on empirical work to make a choice of auction format. Studies of an earlier Treasury auction experiment, auctions in other countries, and the current U.S. experiment are inconclusive as to which auction format is better, but most favor the uniform-price format. While data from the current experiment have not shown that the uniform-price auction format has produced higher revenues for the Treasury, they also have not shown that it has resulted in lower revenues than the discriminatory-price auction. And there is some evidence that participation is higher under the uniform-price format, which might ultimately lead to higher revenues for the Treasury. As the experiment continues and further data are collected, perhaps a more definitive answer can be obtained.

[30]Similarly, the concentration of competitive awards to the top 10 dealers and their customers was reduced by 4 to 9 percentage points for the two-year and five-year uniform-price auctions, but their share increased by 11 percentage points for the three-year notes and remained unchanged for the 10-year notes.