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The Economics of Treasury Securities Markets

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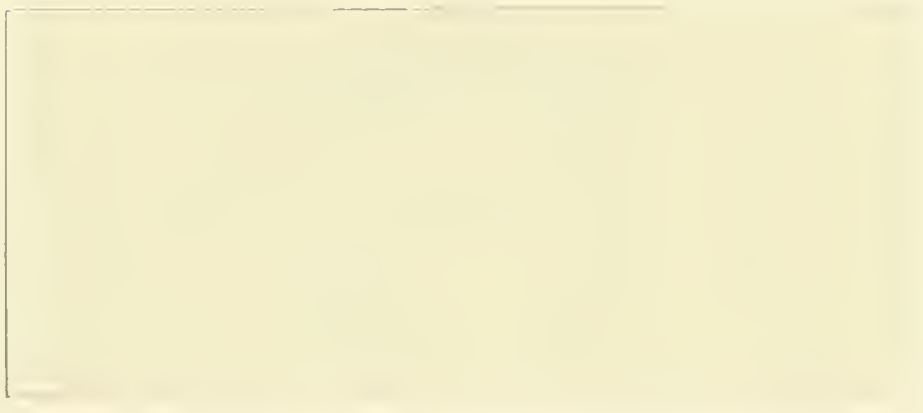

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1 Introduction

Recently, the market for Treasury securities has attracted considerable attention after alleged infringements by Salomon Brothers. Several questions have been raised about the best way of selling U.S. government debt (see the Joint Report on the Government Securities Market (1992)). One issue is whether some auction format other than the currently used discriminatory auction yields greater revenues for the Treasury. Another related question is whether the existing mechanism for selling Treasury securities can be manipulated by buyers.

Our objective is to give an account of what economists have learnt from the analysis of auctions and its implications for Treasury securities markets.[1] In Sections 2 and 3 we describe several auction environments. We discuss static models of auctions in Section 4. After describing the institutional framework of the Treasury securities market, Section 5 continues with a discussion of whether other auction formats might increase the Treasury's revenue, and of issues relating to manipulation and the when-issued market. Policy implications are summarized in Section 6.

2 Types of Auctions

In the four commonly observed auction forms described below, assume that, as is the case with Treasury securities auctions, the seller is conducting an auction for the sale of many identical objects. The first two auctions are sealed-bid auctions and the next two are open auctions.[2]

Discriminatory Auction: Bidders submit sealed bids to the auctioneer. The demands of the bidders, starting with the highest price bidder down, are met until all the objects are allocated. All winning bidders pay the unit price they submitted. This method is used by the Department of Interior to auction oil, minerals, and

[1] For more complete surveys of static models of auctions, see the papers by McAfee and McMillan (1987), Milgrom (1987), and Wilson (1987).

[2] Sometimes, academics and practitioners use conflicting names for different auction formats. For instance, academics refer to a descending-price auction described below as a "Dutch" auction whereas as the financial community refers to a uniform-price auction as a "Dutch" auction (see the Joint Report on the Government Securities Market (1992), pp. B17–B19). We avoid names that may cause confusion.

timber leases.

Uniform-Price Auction: Bidders submit sealed bids to the auctioneer. The demands of the bidders, starting with the highest price bidder down, are met until all the objects are allocated. The winning bidders pay the highest losing bid. (In a discriminatory auction, the winners pay their bids.)

Ascending-Price Auction: Starting with a very low price, the auctioneer calls out an increasing sequence of prices. Bidders indicate their interest in buying at the current price. The auctioneer stops when the demand at the current price equals the supply. The demands of bidders interested in buying at this price are met. This type of auction is commonly used to sell art.

Descending-Price Auction: Starting with a very high price, the auctioneer calls out a decreasing sequence of prices until a bidder buys some of the objects at the current price. The remaining supply is sold using the same method, again starting with a very high price. This auction is used to sell tulips in the Netherlands.

The Department of Treasury had been using a discriminatory auction to sell all its securities (see Section 5.1). Recently, it switched to a uniform-price auction for selling two-year and five-year notes. Other Treasury securities are still sold by a discriminatory auction.[3] Ultimately, the Treasury plans to use an ascending-price auction to sell all its securities (see the Joint Report on the Government Securities Market (1992), page xiv).

3 Bidders' Valuations and their Information

Apart from the rules of the auction, an important way in which auctions differ is in the bidders' knowledge and in the relationship between bidders' values.[4] A bidder's value for a commodity is the maximum amount that he would be willing to pay if he had no uncertainty about any relevant aspect of the commodity. If a bidder is offered the commodity at a price equal to his valuation, he is indifferent between taking it or leaving it. Of course, in a real auction a bidder is unlikely to know his

[3]See "New Process for Auctions to be Tested" in *The New York Times* on September 3, 1992.

[4]Unlike the rules of the auction, the auctioneer may be unable to control the bidders' information and their valuations. These are largely determined by the nature of the objects and other exogenous factors.

value for the objects being auctioned.

Under the *common values assumption*, each bidder has the same value for the objects. This value is unknown at the time of bidding, but each bidder has some private information about the value. This private information is imperfect and any bidder would revise his estimate of the true value if he were to learn the private information of another.

Whenever bidders buy an object for resale rather than for personal consumption, the common value assumption is reasonable. For instance, in an oil lease auction the common value for each bidder is the net revenues from the sale of oil. Because there is uncertainty concerning the quantity of oil in the tract being auctioned, the costs of recovery, and future oil prices, this common value is unknown. Each bidder has his estimate, privately known to him, of the common value. It is usually assumed that this estimate is unbiased: on average each bidder's estimate is correct, although not in every instance.

In a Treasury securities auction, the common value assumption is appropriate because the value for each bidder is a common and unknown resale price. Therefore, we restrict our discussion to the case when this assumption holds.[5]

4 Static One-Shot Auctions

Before discussing Treasury auctions, an analysis of static models of auctions is essential. In particular, we consider the winner's curse and its implications for expected revenues under different auction formats.

4.1 The Winner's Curse

Understanding the *winner's curse* phenomenon is important because many results follow from it.[6] For simplicity, we explain this phenomenon assuming that one object is being auctioned.

In calculating his bid, each bidder faces a trade-off between the probability of winning and his expected profit if he wins. If he submits a high bid, his probability

[5]See the surveys cited in Footnote 1 for auctions where the bidders' values are (i) privately known and independently distributed, or (ii) correlated but not common.

[6]The winner's curse was first observed by Capen, Clapp, and Campbell (1971) in oil lease auctions.

of winning increases but his expected profit conditional upon winning decreases. At the time of determining his bid, if a bidder uses his (unbiased) estimate of the true value to figure out his expected profit upon winning, he will overestimate the true value; if he wins he will make less profit than he expected and may even lose money. Upon winning he learns something striking: all other bidders have estimates lower than his! To see this note that in a common value auction with many bidders, the highest of the bidders' private estimates of the common, unknown value is usually much higher than the true value, even though each bidder's estimate is unbiased.[7] Assuming for simplicity that bidders use similar thumb rules to calculate their bids based on their estimates, the highest bidder (the winner) is usually the one who is most optimistic about the true value. Although the bidders' private estimates are unbiased, each bidder knows that if he wins the auction then his estimate is biased upwards and that others are (relatively) pessimistic about the worth of the object being auctioned. A bidder who fails to take this into account will bid too high and may win the auction but lose money. This phenomenon is called the winner's curse.

The winner's curse has several implications for optimal bidding strategies. First, as the number of bidders increases (and other factors are held constant), it is optimal to bid more conservatively. This is because the highest of, say, ten estimates is likely to be much greater than the highest of two estimates. Thus, the winner's curse is reinforced as the number of bidders increases, causing bidders to shade their bids below their estimates by a greater amount. Nevertheless, the highest bids and the selling price increase as the number of bidders increases.

Second, as the uncertainty about the value of the object decreases, the amount by which the highest estimate exceeds the true value decreases. For example, if bidders can assess the true value to within, say, plus or minus 10%, then the highest estimate will tend to be much lower than if the bidders can assess the true value only to within plus or minus 50%. Thus, if the bidders' estimates are less noisy, then the winner's curse is weaker; consequently, it is optimal for buyers to bid less conservatively as a function of their estimates. Hence, the selling price increases on average as the uncertainty about the true value decreases.

An alternative way of seeing this is the following. Consider an auction where the

[7]One can easily verify this with the following experiment. A glass jar full of pennies is shown to a group of people and each person is independently asked to guess the number of pennies in the jar (without actually emptying the contents of the jar and counting the pennies). Almost always the highest guess will be much greater than the actual number of pennies in the jar although the average of the estimates may be close to the truth.

object being sold is a jar of pennies and everyone knows the number of pennies in the jar (because the seller counts the pennies in front of everyone). No matter which auction format is used, it is optimal for each buyer to bid either the true value or a penny less than the true value. The profit that buyers can make is (close to) zero. On the other hand, if bidders do not know the number of pennies with certainty but their guesses are unbiased and they are sophisticated, then the selling price will be less than the true value on average, and the bidders' expected profits will be strictly positive.

It may seem paradoxical that when bidders have less information they make more money. However, the puzzle resolves when one interprets each bidder's expected profit as the rent he earns from his private information (that is, from his private estimate of the true value). If the true value is known to everyone, then no one has private information and the expected profit is zero. If the true value is uncertain, then bidders who possess private information earn positive expected profit, and the more uncertain the true value the greater the expected profits for these bidders. In turn, the greater the uncertainty about the true value the lower the seller's revenues.

The last point is important because the expected revenue rankings for different auction formats, discussed next, follow from it.

4.2 Expected Revenue Rankings for Static Auctions

As per our discussion in Section 4.1, the key to understanding which auction format is most favorable to the seller is a comparison of the amount of information revealed during the auction.[8]

In a discriminatory auction the winners pay their bids whereas in a uniform-price auction the winners pay the highest losing bid.[9] Therefore, one might think that a uniform-price auction leads to lower expected revenues. This is contrary to the prediction of the theory. First, bidders are aware of the auction procedure and compensate by bidding more in a uniform-price auction; this factor alone would lead to equal expected revenues in the two types of auctions. Second, the price paid by a winner in a uniform-price auction depends on the private information of the highest losing bidder (through the highest losing bidder's bid). The price a winner pays does

[8]Most of this section is based on Milgrom and Weber (1982a).

[9]Our discussion hereafter also applies to auctions with more than one unit for sale. It is assumed, however, that each bidder wants only one unit.

not depend on his own bid, even if his signal is overly optimistic and his bid too high. Thus, the winners' curse in a uniform-price auction is lower than in a discriminatory auction. Consequently, bidders bid even more aggressively in a uniform-price auction than they would if they were merely compensating for the difference in the auction procedures. The average selling price in a uniform-price auction is greater than in a discriminatory auction.

Next, observe that an ascending-price auction reveals at least as much as a uniform-price auction about bidders' private information. In both these auctions the price paid by the winners is the bid of the highest losing bidder. In addition, in an ascending-price auction bidders may learn something about the private estimates of other bidders by observing their interest (or lack of it) in buying the objects for sale. This decreases the winners' curse in an ascending-price auction, which causes bidders to be more aggressive than they would be in a uniform-price auction. Consequently, the average selling price in an ascending-price auction is greater than in a uniform-price auction.

When many units are auctioned, a descending-price auction reveals more information than a discriminatory auction.[10] During a descending-price auction, bidders learn something about the private information of previous buyers. This decreases the winners' curse, causing bidders to bid more aggressively for the remaining units. Thus, the average selling price in a descending-price auction is greater than in a discriminatory auction.

To summarize, the prediction is that in static one-shot situations, an ascending-price auction yields greater expected revenues to the seller than a uniform-price auction which in turn yields greater revenues than a discriminatory auction. In addition, a descending-price auction is also better from the seller's viewpoint than a discriminatory auction. In general, nothing can be said about the revenue comparison between ascending-price and descending-price auctions; it depends on variables like number of objects being sold, number of bidders, and probability distributions of the common value and the bidders' estimates.

Should the seller reveal any relevant information that she has before the auction? It should be clear from the discussion in Section 4.1 that on average the seller is

[10]When only one unit is being auctioned, a discriminatory auction is equivalent to a descending-price auction in the sense that the optimal strategy for bidders in each of the two auctions turns out to be the same. When many identical units are sold, as in Treasury auctions, these two types of auctions are not equivalent.

better off if she honestly reveals what she knows about the objects for sale as this decreases the winners' curse. In the long run it is to the seller's advantage if she precommits to tell the truth, even though in specific instances, when her information is unfavorable, she may derive a short-term benefit by reneging on this commitment.

There are two limitations of these results. First, the assumption that bidders are sophisticated and take the winners' curse into account may be incorrect. Several experimental studies find that inexperienced bidders are susceptible to the winners' curse (see Kagel (1992) and the references cited there). If bidders are inexperienced, some of the revenue comparisons described above may be reversed. The release of public information, or a switch from a discriminatory to an ascending-price auction may decrease revenue because more information curtails the enthusiasm of naive optimistic bidders. Presumably, bidders in Treasury auctions are aware of the winners' curse; if they were not, they would make less than normal or even negative profit and ultimately would be eliminated.

The second limitation may be more serious. In most auction models it is assumed that each bidder wants only one indivisible unit of the objects being sold. (We shall refer to this as the unit demand assumption.) If bidders want more than one unit and are allowed to submit demand functions, then Wilson (1979) has shown that the average price can be lower. It is not known whether the revenue rankings described above can be reversed if the unit demand assumption is relaxed.[11,12]

5 The Treasury Securities Markets

In Section 5.1 we give a brief description of the organization of the four Treasury securities markets: auction, forward market, secondary market, and repurchase and reverse market. We discuss, in Section 5.2, the rankings of different auction formats from the point of view of the Treasury, under the assumption that bidders do not manipulate the auction. This discussion is qualified in Section 5.3 where we consider

[11] More recently, Back and Zender (1992) also show that if the unit demand assumption is relaxed then discriminatory auctions can yield higher revenues than uniform-price auctions.

[12] Maskin and Riley (1989) show that in the independent and private values model the unit demand assumption is crucial for revenue-equivalence results.

the possibility that bidders can collude or attempt to corner the market. Finally, in Section 5.4 we discuss the interaction between the forward market and the auction.

5.1 Institutional Details

Every week the Department of Treasury auctions 13 week and 26 week bills. Less frequently, the Treasury auctions notes and bonds with longer maturities; see Fabozzi (1991, pp. 175-177) for an auction schedule. Currently, there are 38 *primary dealers* who can submit sealed bids at the auction. A bid submitted by a primary dealer consists of a price and a quantity that the dealer is willing to buy at that price.[13] These price-quantity pairs are called *competitive bids* and primary dealers are often referred to as *competitive bidders*. Although primary dealers may submit as many price-quantity bids as they like, often they each submit only one or two bids. The *noncompetitive bidders*, mainly individual investors, submit sealed bids that specify only the quantity sought, up to a maximum specified by the Treasury. The noncompetitive bids always win at a price equal to the quantity-weighted average of the winning competitive bids.[14] The competitive bidders compete for the remaining units in a discriminatory auction.[15] That is, the demands of the bidders, starting with the highest price bidder down, are met until the supply is allocated. Winning competitive bidders pay the unit prices they submitted. After the auction, the Department of Treasury announces summary statistics about the bids submitted. These include total tender amount received, total tender amount accepted, highest winning bid, lowest winning bid, proportion of bids accepted at the lowest price, quantity-weighted average of winning bids, and the split between competitive and noncompetitive bids. The Treasury securities are delivered to the winning bidders a few days after the auction and can be resold in an active secondary market.

There is also a forward market for Treasury securities. After an announcement of the amount of securities to be auctioned by the Treasury, primary dealers begin trading (among themselves and for their institutional clients) forward contracts on the

[13] Actually, bidders submit discount rate-quantity pairs. For expositional convenience, our discussion here is in terms of price-quantity pairs.

[14] The Fed also participates in the auction, both on its own account and as an agent for foreign central banks. The Fed can roll over maturing bills up to a pre-announced amount. Like noncompetitive bidders, the Fed always win and buys the bills at the quantity-weighted average of the winning competitive bids.

[15] Recently, the Treasury has started using a uniform-price auction to sell some of its securities. See the last paragraph of Section 2.

Treasury securities to be auctioned.[16] The delivery date for these forward contracts is the issue date of the underlying Treasury securities. Thus these forward contracts are called "when-issued". Positions in the when-issued market are settled either by closing them before the maturity dates of the contracts or by delivering the underlying securities. The open interest in the when-issued market varies from a small amount to several times the amount auctioned.

The when-issued market serves two functions. First, it is a forward market. Many institutional buyers use the when-issued market to ensure that they get Treasury securities to be auctioned. Primary dealers often take short positions on the when-issued market before the auction by selling forward contracts to their institutional clients. The second function of the when-issued market is to aggregate, at least partially, the diverse information and beliefs held by the participants of the market about the demand for the Treasury securities to be auctioned.

A *short squeeze* occurs when many of those who have a short position in the when-issued market fail to acquire the Treasury securities in the auction. They are then forced to pay dearly either to close out their positions or to borrow the Treasury securities in the *repurchase and reverse* market, commonly known as repo and reverse market, to deliver. The repo and reverse market is a market for short-term borrowing and lending that is collateralized by securities (see Stigum (1989)). If one needs to borrow funds overnight, one can sell some securities to a counter party and at the same time sign with her an agreement to repurchase these securities the next day at a predetermined price. This predetermined price may be equal to the selling price paid on the previous day by the counter party. In this case, the counter party is paid an explicit repo rate on the money she invests. Alternatively, the purchase price is set to be different from the selling price so that the counter party earns the returns due to her. In either case, the return earned by the counter party is the so-called repo rate for the securities used as collateral. The counter party in a repo agreement is said to be engaged in a reverse repo — borrowing securities while loaning out funds. When there is a short squeeze, say in the when-issued on the two-year Treasury notes, the repo rate using the newly auctioned two-year Treasury notes as collateral might decrease dramatically and can even become negative. This is because these notes become scarce. In this event, these two-year notes are said to be traded "special".

[16] A standard forward contract for Treasury bills is for a principal amount of $5 million. The principal amounts for Treasury notes and bonds are higher.

5.2 Expected Revenue Rankings for Treasury Auctions

Although the core of the Treasury securities market is a discriminatory auction, there are several ways in which this market differs from the static discriminatory auction discussed in Section 4.[17] The quantity demanded by noncompetitive bidders renders the net supply of Treasury securities uncertain. As a first approximation this may be ignored because the total amount of noncompetitive bids does not fluctuate much.[18] Trading in the when-issued market before the auction plays an important role in influencing the expected revenue generated in the auction. However, it impacts upon different auction formats similarly. Thus we postpone our discussion on the connection between the when-issued market and the auction till Section 5.4. The existence of a secondary resale market is important because it has implications for expected revenue rankings of different types of auctions.

The competitive bidders in Treasury auctions are large financial institutions. Their information about the term structure of interest rates and the demand for Treasury securities tends to be better than the information possessed by the smaller institutions and individual investors who buy in the secondary market. Often, buyers in the secondary market only have publicly known information such as the auction statistics announced by the Department of Treasury. Further, competitive bidders typically hold a large inventory of fixed income securities and would benefit from favorable information about the movement of interest rates.[19] To the extent that bids submitted in the auction reveal the private information of competitive bidders, the secondary market prices for all kinds of fixed income securities will be responsive to these bids.[20] This creates an incentive for bidders to bid higher (than they would have if the secondary market buyers did not learn from the auction) in order to signal to the buyers in the secondary market that their (the bidders') private information is very favorable. This informational linkage between the actions of the bidders and the resale price is absent in the static auctions discussed in Section 4.[21]

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[17]This discussion is based on Bikhchandani and Huang (1989).

[18]Later, we discuss whether small investors should buy on the secondary market or submit noncompetitive bids.

[19]Usually, the value of a fixed income security goes up when the interest rates go down.

[20]See Cammack (1991) for empirical evidence that the secondary market reacts to information in the auction.

[21]The analysis in Bikhchandani and Huang (1989) ignores the fact that competitive bidders usually carry a large inventory of fixed income securities. However, Bikhchandani and Huang assume that

Recall from Section 4.1 that as the amount of information revealed about the objects for sale increases, the winners' curse becomes weaker, the bidders become more aggressive, and the seller's expected revenue increases. This key insight from an analysis of static one-shot auctions remains relevant. However, the link between the secondary market and the auction must also be considered. If too much information is revealed before or during the auction, then the secondary market buyers learn very little from the bids submitted. Consequently, the resale price will not be very responsive to the bids. This can decrease the bidders' incentives to bid higher in order to signal their information to the secondary market buyers. However, under mild conditions[22] this does not happen. Additional information revelation increases the competitive bidders' bids. The only other factor to be considered in ranking different auction formats by expected revenue is the cost to the bidders of signaling to the secondary market.

Because in a discriminatory auction the price paid by a winning bidder is his bid, and in a uniform-price auction the price paid by a winning bidder does not increase with his bid, it is cheaper for a bidder in a uniform-price auction to bid high in order to signal favorable private information.[23] Second, as noted in Section 4.2, more information is revealed in a uniform-price auction than in a discriminatory auction. This weakens the winners' curse but, assuming the condition mentioned in Footnote 22, does not decrease bidders' incentives to signal. These two factors cause the bids and the average winning price to be higher in a uniform-price auction than in a discriminatory auction.

The cost to bidders of signaling to the resale market is the same in a descending-price auction and in a discriminatory auction, because winning bidders pay their bids in both of these auctions. However, in a descending-price auction the information revealed about previous sales induces the bidders to be more aggressive, but does not decrease the bidders' signaling incentives. The prediction is that descending-price auctions yield greater expected revenue than discriminatory auctions.

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the competitive bidders participate in the auction solely for the purpose of resale, and thus have an incentive to signal their private information.

[22]Roughly speaking, bidders' private information should be complementary in a certain sense. For instance, if an important aspect of each bidder's private information is the quantity of orders placed by their clients, this condition is satisfied.

[23]Sometimes, in a uniform-price auction, one or a few bidders may find it profitable to bid an arbitrarily high price because they do not pay what they bid. This may lead to an unstable situation or may scare away other bidders. In order to avoid this possibility it may be necessary to impose a maximum bid price.

In an ascending-price auction the seller keeps raising the asking price until the total number of units that (the winning) bidders are willing to buy equals the number of units for sale. Thus the seller does not know and therefore cannot reveal the bids of the winning bidders. All that he can reveal to secondary market buyers are the bids at which the losing bidders dropped out. Although the secondary market resale price increases with the level of all bids including losing ones, losing bidders have less reason than winning bidders to raise the resale price.[24] Winning bidders would like to signal to secondary market buyers and raise the resale price but they cannot credibly reveal their bids. Thus bidders in ascending-price auctions do not have a strong incentive to signal favorable private information, either because they (the winners) cannot or because they (the losers) do not care to. This tends to decrease their bids when compared to the other three auctions formats. However, as noted in Section 4.2, more information is revealed during an ascending-price auction than in either a uniform-price auction or a discriminatory auction. This tends to increase the bids in an ascending-price auction. The net effect of these two conflicting factors is ambiguous, and in general it is not clear whether ascending-price auctions generate greater expected revenues than discriminatory auctions or uniform-price auctions.

To summarize, provided there is no manipulation by bidders, both descending-price auctions and uniform-price auctions yield greater expected revenues than discriminatory auctions. Unlike in static auctions, it is difficult to predict whether ascending-price auctions are better than any of the other auction formats.

Should the seller publicly announce any relevant information she has before the auction? As in Section 4.2, if the seller truthfully reveals what she knows, then the winners' curse decreases. Moreover, if the bidders' and the seller's information satisfy the mild condition mentioned in Footnote 22, by revealing her private information the seller does not decrease the bidders' incentive to signal to the resale market. Thus bidders bid higher if the seller reveals her private information. Honesty is the best policy for the seller.

The price paid by noncompetitive bidders is the average winning price. Because this price is less than the secondary market price of comparable securities, small buyers are better off if they submit noncompetitive bids instead of buying on the

[24]It is true that if losing bidders signal favorable information through their bids, the value of their portfolio of fixed income securities increases. However, conceivably, the resale price of the security being auctioned is much more responsive to signaling through the auction than the prices of other fixed income secutities. A losing bidder does not possess the auctioned security.

secondary market.[25] Noncompetitive bidders free-ride on the information collected by competitive bidders. As there is an upper limit on the amount of each noncompetitive bid, buyers with large orders cannot satisfy their demand through noncompetitive bids.[26]

5.3 Manipulation

Our analysis in Section 5.2 assumes there is no manipulation of the market mechanism by bidders. Certain behaviors, such as explicit collusion in the auction or cornering more than 35 per cent of any particular security, are illegal. One could take the view that in choosing between different auction formats such behavior should be disregarded because if it occurs, violators will be severely punished. However, all violations of the law are not detected. Thus, an important criterion in selecting an auction format is invulnerability to abuse. It seems to us that discriminatory auctions and descending-price auctions are less susceptible to manipulation than uniform-price auctions and ascending-price auctions.

5.3.1 Collective Manipulation

It has been alleged that bidders in Treasury securities auctions often collude.[27] If bidders talk to each other before the auction merely to share their private information but not to fix prices then the winners' curse is diminished and auction revenues increase. Whether collusion and price-fixing is widespread among competitive bidders is an empirical question. A careful analysis of the data may provide some clues.[28]

Friedman (1960, pp. 64-65) argues that in a discriminatory auction bidders have a strong incentive to collude; furthermore, this type of auction discourages nonspecialists from participating. He claims that a uniform-price auction does not suffer

[25]Cammack (1991) compared the secondary market prices of off-the-run Treasury bills with the auction prices of 13 week Treasury bills and discovered an underpricing in the auction by a discount rate of 4 basis points. (One basis point is one-hundredth of one percent.) Spindt and Stolz (1991) found an underpricing of 7 basis points. Given that off-the-run Treasury securities usually sell at a discount compared to their on-the-run counterparts, these numbers serve as a lower bound on the magnitude of the underpricing.

[26]Currently, these limits are $1 million for bills and $5 million for notes and bonds.

[27]See, for example, "Hidden Bonds: Collusion, Price-Fixing have long been Rife in Treasury Market" in *The Wall Street Journal* on August 19, 1991.

[28]A test for detecting collusion using auction and when-issued data can be found in Bikhchandani and Huang (1992).

from these drawbacks, and consequently will yield greater revenues to the Treasury than a discriminatory auction.[29]

Although we claim that in the absence of any manipulation by bidders, uniform-price auctions yield greater revenue than discriminatory auctions, our reasons are different from Friedman's. First, we do not think that discriminatory auctions give bidders a greater incentive to collude. If there is no collusion under either auction format then, as pointed out in Section 5.2, uniform-price auctions yield greater revenue than discriminatory auctions. Therefore, assuming that the average secondary market price is the same under both auction formats, bidders prefer a discriminatory auction to a uniform-price auction. The strong incentives for collusion that Friedman claims discriminatory auctions induce cannot be because bidders' profits are lower.[30]

We are not aware of any formal analysis of collusion under the common and unknown values assumption appropriate for Treasury auctions. However, the following form of implicit collusion seems plausible under a uniform-price auction. In a Treasury auction, each bidder is allowed to submit many price-quantity bids. Suppose that every bidder submits two bids, one at a high price P_H and another at a very low price P_L. If the total quantity demanded at P_H is higher than the total supply then P_L is the highest losing bid and the price paid by the bidders. Thus bidders collude on price and compete with each other only through the quantity submitted at P_H.[31,32] If any bidder deviates from this implicit agreement, then starting with the next auction, bidders go back to competing on price and quantity for a sufficiently long period to make this deviation unprofitable. As in any cartel, the smaller the number of members the greater the likelihood of collusion. One may think that because there are 38 competitive bidders in Treasury auctions it will be difficult for them to collude. However, several of the 38 bidders are much larger than the rest.

If the rules of the uniform-price auction are changed so that the price paid by

[29]Friedman's proposal started a debate on this question in the 1960s. See the references cited in Bikhchandani and Huang (1989). For a critique of Friedman's proposal in light of recent events, see Reinhart (1992).

[30]In fact, when the bidders' values are identical and common knowledge, it is easier to sustain collusion in a uniform-price auction than in a discriminatory auction. See Milgrom (1987) and the references cited therein.

[31]As the total demand at P_H exceeds the total supply, each winning bidder gets an amount less than and proportional to his demand at P_H.

[32]Of course, in deciding how much to bid each bidder must keep in mind that he cannot acquire more than 35% of the total supply and cannot submit a quantity more than the total supply.

each winning bidder is the market clearing bid (P_H in this case) rather than the highest losing bid, then this form of collusion is not profitable. However, a variation in which the total demand at P_H is less than the total supply may still be possible in a uniform-price auction with the market clearing bid as the price, and in an ascending-price auction. This would require explicit communication among bidders. Clearly, this form of collusion is not possible in either discriminatory auctions or in descending-price auctions.[33]

5.3.2 Individual Manipulation

A bidder can manipulate the Treasury securities market by cornering the market, *i.e.*, through a short squeeze. If there are many bidders with short positions on the when-issued market and one bidder successfully bids for a large amount at an unusually high price in the auction, then this bidder can obtain a high price in the secondary market, the when-issued market, or in the repo and reverse market. All those who took short positions on the when-issued market are forced to buy or borrow from this bidder, as he owns most of the units sold at the auction.

When there is a short squeeze, the bidder who corners the market buys most of the units auctioned and pays a high price. This may lead one to believe that a short squeeze is good for the Treasury as it increases auction revenues.[34] It is true that when there is a short squeeze, the auction prices are higher and the Treasury benefits in that specific auction. The primary dealers who are squeezed get hurt. Large primary dealers are more likely to squeeze the market, and if they do it often they will drive other primary dealers out of the Treasury market. If short squeezes occur freguently then in the long run there will be fewer competitive bidders in the auction and, consequently, lower revenues for the Treasury.

It is illegal to corner the market — no bidder may buy more than 35 per cent of the supply in any Treasury auction. Thus in order to corner the market a bidder would have to submit bids through several agents who give the appearance of acting independently. The ease with which a bidder can do this depends more on the

[33]Sometimes, auctioneers use a secret (unannounced) reservation price to discourage collusive behavior. If they suspect collusion, they refuse to sell. However, assuming that the Treasury could call off an auction when it suspected manipulation, this would seriously undermine the confidence of bidders in the Treasury securities market.

[34]See an editorial titled "Salomon and the Treasury Cartel" in *The Wall Street Journal* on August 20, 1991, and an article titled "Don't Let Salomon Doom T-Bonds" by William E. Simon in the March 30, 1992 issue of the same journal.

reporting requirements and the extent of law enforcement than on the specific auction format. However, assuming that a bidder can bid through several agents without detection, it seems to us that a uniform-price auction is more vulnerable to a short squeeze. In a uniform-price auction, if one bidder submits bids for a large total amount at very high prices then he can be sure of cornering the market. The price paid is the highest among the others' bids, or slightly less. A bidder in a discriminatory auction can also corner the market by bidding at very high prices. However, it is costly for this bidder to do so as the price he pays is his bid. Similar arguments imply that a descending-price auction is less susceptible to being cornered than an ascending-price auction.

There is another way in which a bidder may find it profitable to manipulate Treasury auctions. Because the same set of bidders participate in the auction every week, it may be worthwhile for a bidder to build a reputation for bidding aggressively (see Bikhchandani (1988)). A bidder with such a reputation intensifies the winners' curse for his opponents; they realize that if they beat the aggressive bidder he must have very unfavorable information. This causes the aggressive bidder's opponents to bid more conservatively, which weakens the winner's curse for the aggressive bidder. In a uniform-price or an ascending-price auction it is very profitable to be the only bidder with this kind of a reputation because, upon winning, the aggressive bidder does not pay his bid; he pays the highest losing bid which would tend to be low as others are scared into bidding conservatively.

An important aspect of each bidder's private estimate of the true value is the demand for Treasury securities from their clients. Consequently, a bidder who usually buys large amounts at the auction would tend to have more accurate information. The presence of such a bidder strengthens the winners' curse for the others. Thus, it may be relatively easy and even more advantageous for a dominant primary dealer to build a reputation for aggressive bidding.

It is true that even in discriminatory auctions and in descending-price auctions, an aggressive bidder's opponents tend to submit lower bids and thus the aggressive bidder wins more often. However, each time he wins, the aggressive bidder has to pay his bid. This makes it costly for a bidder to build and maintain a reputation for aggressive bidding. Discriminatory auctions and descending-price auctions are less vulnerable to such reputation formation.

5.4 The When-Issued Market

The when-issued market performs two key functions. First, it is a forward market for Treasury securities. Second, it aggregates the diverse information and beliefs of the participants in this market. Those who believe that interest rates will fall are long, and those who believe otherwise are short. The prices of these when-issued contracts are known to primary dealers and their institutional clients.[35]

In another paper (Bikhchandani and Huang (1992)) we present some empirical evidence on the when-issued market and the auction for 13 and 26 week bills. We show that the previous week's auction data and when-issued price changes do not carry much information about this week's auction, given the when-issued price at the time of the current auction. This implies that the when-issued market aggregates information efficiently.

We also present evidence of strategic interplay between the when-issued market and the auction. The data suggest that the traders in the when-issued market take into account the possibility that the when-issued prices might reveal some of their private information. This may raise the price they eventually pay. If instead of buying in the when-issued market, traders with large demands buy mainly in the auction, their private information will get revealed only after the auction. Thus the auction prices are expected to be more informative than the when-issued prices at the auction time. However, during a short window after the auction and before the announcement of the auction results, the when-issued prices can be quite informative about the information innovation contained in the auction bids. This is consistent with the idea that post-auction trading in the when-issued market has no information costs in relation to the auction and thus participants in the when-issued market trade according to their information at this time.

It is not clear whether the when-issued market increases the Treasury's revenues in the subsequent auction. The information aggregation in the when-issued market weakens the winners' curse and tends to increase the average winning price. The impact on bidders' incentive to signal through their bids in the auction is ambiguous. The information revelation in the when-issued market may decrease the overall signaling incentive for the bidders.[36] Moreover, primary dealers who take short po-

[35]It is becoming easier to have access to bid and ask quotes of all fixed income securities. One can rent a Blumberg terminal. The Electronic Joint Venture (EJV), formed by many primary dealers, also competes with Blumberg in providing data on fixed income securities to investors.

[36]The mild regularity condition mentioned in Footnote 22 may not be satisfied here as the infor-

sitions in the when-issued market would like to cover their positions in the auction, but at the same time, in case they are unsuccessful, would not be keen on pursuing strategies that raise the when-issued market price or the secondary market price after the auction. Those with long positions have a greater incentive to signal. We conjecture that if the signaling incentive of the buyers is weak to begin with, then the information revealed in the when-issued market raises the average auction price. However, we do not know of any theoretical analysis of the net impact of the when-issued market on the prices in the subsequent auction. This issue cannot be decided empirically, unless auctions are held without the existence of a when-issued market.

Although the when-issued market performs the two important functions mentioned above, it also provides new avenues for manipulation of the Treasury securities market. For instance, a bidder with very favorable information may refrain from taking a long position in the when-issued market, and instead take a short position to falsely signal unfavorable information. He can then win in the auction at a price lower than he otherwise would. If he wins a large enough quantity in the auction, this could even result in a short squeeze.

6 Policy Implications

We predict that, in the absence of manipulation by bidders, uniform-price auctions and descending-price auctions will yield the Department of Treasury greater expected revenues than discriminatory auctions. Furthermore, unless there are other constraints, the Department of Treasury should follow a policy of reporting any information, positive or negative, that may affect the resale prices of its securities.

We are unable to estimate the predicted increase in the Treasury's revenues after a change in the auction format. Assuming that the auction mechanism or the Treasury's information revelation policy do not change the *ex ante* expected secondary market prices of the securities, a weak upper-bound on the increase in revenue may be obtained by estimating bidders' expected profits. The Treasury's revenues cannot increase by more than the bidders' current profits because bidders will not participate unless they make money. However, it is very difficult to estimate the primary dealers' profits from participating in the Treasury auction. Data regarding their costs are not publicly available. In addition, primary dealers have several sources of Treasury

mation incorporated in the when-issued prices is likely to be a substitute for the bidders' private information rather than a complement.

auction related income. They can sell short on the when-issued market and cover their positions in the auction. The contribution of this to their profit is impossible to estimate because data on the volume of when-issued market trades by the primary dealers are not available. Primary dealers can also buy in the auction and sell in the secondary market. Cammack (1991) estimates that during the period 1973–1984, the total return to all primary dealers who bought 13 week bills in the auction and sold in the secondary market was approximately $110,000 per $1 billion face value. Using data from the period January 1986 to June 1991, Jegadeesh (1992) estimates the analogous return at $432,000 per $1 billion face value for 2, 5, and 7 year notes, and 10 year bond.

Last year's events involving Salomon Brothers emphasize the importance of discouraging bidders from cornering an issue or otherwise manipulating the market. Although our discussion in Section 5.3 is mainly conjectural, we think that both uniform-price and ascending-price auctions are more susceptible to manipulation than either discriminatory or descending-price auctions. Uniform-price auctions (and perhaps ascending-price auctions) yield greater revenue than discriminatory auctions if there is no manipulation. However, if the Treasury switches to a uniform-price auction or an ascending-price auction, its revenues may fall since bidders may find it easier to collude or game the auction in one of the other ways mentioned in Section 5.3.2.[37]

Several of the reforms outlined in the Joint Report on the Government Securities Market (pp. xiii-xvi) relate to discouraging manipulation by bidders. One proposed reform is to reopen the market and supply additional securities if a "protracted short squeeze develops, regardless of the reason for the shortage." This policy may have substantial costs. The uncertainty associated with the auction will increase and primary dealers will be more conservative in their bidding since there is always a chance that after the auction the Treasury will increase the supply and decrease prices.

The when-issued market, like any forward market, performs a useful function for its participants. There are two consequences of this market that are important for the Treasury. First, the when-issued market aggregates bidders' private information. As discussed in Section 5.4, the effect on the average selling price is ambiguous. Second, it opens up an avenue for manipulating the Treasury securities market. A bidder may find it profitable to corner the units sold in the auction in order to squeeze bidders

[37]A change to an ascending-price is being considered. See the Joint Report on the Government Securities Market (1992), page xiv.

who take short positions on the when-issued market.

The Joint Report (page xiii) has also suggested that Treasury auctions be opened up so that buyers with smaller demands (those who normally buy on the secondary market) are encouraged to participate in the competitive bidding. We believe that a change in the auction rules will not increase participation. Smaller bidders tend to be less well-informed as their size reduces their incentive to gather costly information.[38] Thus, smaller competitive bidders would be at a disadvantage.[39] Even if the Treasury tried to make it easier for them to participate they may prefer not to. They are best off submitting noncompetitive bids. This enables them to buy at the average price paid by primary dealers without incurring any information collection costs.

Most of the results reported in this paper are based on theoretical models. There has been little by way of empirical testing of revenue ranking predictions of the theory. A major problem is the lack of data-sets with changes in the auction format.[40] The U.S. Department of Treasury has used a discriminatory auction until now, except for a brief period in the 1970s when it experimented with a uniform-price auction. Recently, the Treasury has switched to a uniform-price auction to sell two-year and five-year notes. This provides an opportunity to test the theory.

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[38]One of the pieces of private information that primary dealers have is the demand from their customers. Competitive bidders who buy only for themselves would not have such information.

[39]See Milgrom and Weber (1982b).

[40]Mexico and Italy have experimented with different methods for selling government debt. Umlauf (1992) suggests that the Government of Mexico increased the average selling price for its T-bills by switching from a discriminatory auction to a uniform-price auction. The Government of Italy switched in the opposite direction — from a uniform-price to a discriminatory auction. We are not aware of any studies comparing revenues before and after the change in the Italian auction.

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