Investigating How Markets Work: Two Perspectives

Many of us in the United States give little thought to how the prices of the products and financial assets that we buy are determined. When the price of coffee goes up, people say, "it's the law of supply and demand." The concepts are as old as economics itself.

Although the U.S. is often characterized as a "capitalist" country where we have "free markets" and "competition" that allow the forces of supply and demand to set prices for goods and services, many Americans don't stop to consider how, or whether, such mechanisms actually work. We take for granted that markets work—at least that they work well enough so that, when we arrive to buy goods or services, we don't have to stand in line a long time. This is not the case everywhere, however, and some countries, such as the Soviet Union and China, are actually trying to introduce more market forces of supply and demand into their economies.

What is it that makes markets function well? And how do alternative types of price-setting mechanisms perform differently? Economists continue to study these questions, and have been going beyond the introductory textbook explanation of supply and demand. This issue of the *Business Review* is devoted to explaining two approaches used in recent economic research on how markets function. One approach is empirical, but uses experimental methods—like a lab experiment, it sets up simplified markets in a laboratory environment and observes how prices adjust to equate supply and demand. The other approach is theoretical—it models auction markets as strategic games, and finds that the rules of the game affect how supply and demand determine price.

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Going, Going, Gone: Setting Prices With Auctions

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Each week when the U.S. Treasury auctions off billions of dollars of Treasury bills, it is setting prices with a mechanism that is over 2000 years old. Auctions are used to sell a wide range of objects, from art works to drilling rights to government contracts—and the stakes are high. On November 13, 1987, the *Wall Street Journal* reported that Van Gogh's "Irises" was auctioned for a record $53.9 million dollars (beating the March 1987 record of almost $40 million paid for Van Gogh's "Sunflowers"). On September 30, 1980, U.S. oil companies paid $2.8 billion in an auction for drilling rights on 147 tracts in the Gulf of Mexico. In another auction, a consortium of Phillips Petroleum and Chevron USA bid $333.6 million to win the offshore drilling rights near Point Arguello, California; their bid was over twice the next highest offer.[1]

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[1]The drilling rights examples are from Paul R. Milgrom and Robert J. Weber, "A Theory of Auctions and Competitive Bidding," *Econometrica* 50 (September 1982), and Marc Levinson, "Using Science to Bid for Business," *Business Month* (April 1987), respectively.

The longevity of auctions, the variety of objects sold through auctions, and the enormous volume of business done in auctions today point to the importance of understanding the economics of auctions. Economists have developed theoretical models to try to answer a number of questions about auctions. What are the advantages of using an auction to set the price of an object? Which set of auction rules should the seller use? And given a particular set of auction rules, what is the buyer's best bidding strategy? The answers to these questions will be important to anyone who participates on either side of an auction transaction, including government procurers, government debt managers, investors, collectors, and businesses.

FINDING THE RIGHT PRICE

Auctions as Price-Setting Mechanisms. Auctions, which have been used since ancient times (see 2500 YEARS OF AUCTIONS...AT A GLANCE), are one of the basic mechanisms for determining the prices of goods to be exchanged.[2] Two other mechanisms are posted prices and negotiated prices. Retailers usually post a price for each good they want to sell, and individual buyers have little choice but to take it or leave it. Sellers find posted prices inexpensive to manage, but in the short run, they are inflexible to changes in demand or to changes in an individual buyer's tastes since there is a lag between the time the price is set and the product is sold. Also, posted prices cannot reflect subtle variations in quality among different units of a particular product being sold. When prices are negotiated, both buyers and sellers influence the price substantially, haggling back and forth. Manufacturers usually negotiate the price of

[2]This discussion is based upon Paul R. Milgrom, "The Economics of Competitive Bidding: A Selective Survey," in Leonid Hurwicz, David Schmeidler, and Hugo Sonnenschein, eds., *Social Goals and Social Organization: Essays in Memory of Elisha Pazner* (Cambridge: Cambridge University Press, 1985).

2500 Years Of Auctions...At A Glance

One of the earliest reports of an auction was by Herodotus who described the bidding of men for wives in Babylon around 500 B.C.[a] This auction was unique since bidding sometimes started at a negative price.[b] Some scholars interpret the Biblical story of the sale of Joseph into slavery as an even earlier reference.[c] In ancient Rome, auctions were used in commercial trade and were held in the *atrium auctionarium* where goods could be displayed prior to sale. Auctions were also used to liquidate property by Romans in financial straits. Caligula auctioned off family belongings to cover his debts and Marcus Aurelius held an auction of royal treasures to finance a state deficit. Plundered war booty was often sold at auction. The most notable auction in Rome was held in 193 A.D. when the Praetorian Guard put the whole empire up for auction. After killing the previous emperor, the guards announced they would appoint the highest bidder as the next emperor. Didius Julianus outbid his competitors, but after two months he was beheaded by Septimius Severus who seized power. (A winner's curse?) In China, auctions were used as early as the 7th century A.D. to sell the belongings of deceased Buddhist monks. In colonial America auctions were used to liquidate inventories, unload importers' unsold items at the end of the season, and sell secondhand furniture, farm equipment, and animals. Evidently the auction was considered a disreputable way of selling goods since the owner's name was usually concealed. The most infamous auctions in American history were the slave auctions held before the Civil War.

[a]Unless otherwise noted, the historical facts presented are from Ralph Cassady, Jr., *Auctions and Auctioneering* (Berkeley: University of California Press, 1967), Chapter 3.

[b]Martin Shubik, "Auctions, Bidding, and Markets: An Historical Sketch," in R. Engelbrecht-Wiggans, M. Shubik, and R. Stark, eds., *Auctions, Bidding, and Contracting: Uses and Theory* (New York: NYU Press, 1983) p. 39.

[c]Paul Milgrom, "Auction Theory," p. 1.

their inputs with their suppliers and most people negotiate the price of a car or a house. While negotiated prices allow all aspects of the product and situation to be taken into account, they can be expensive and time-consuming, as different offers and counteroffers must be considered one at a time.

The auction mechanism falls somewhere in between posted and negotiated prices. In auctions, sellers set the rules and prices are determined by competition among potential buyers. Auctions are more flexible than posted prices. Since the price in an auction is set at the same time the object is sold, it reflects current demand conditions, the latest information, and the tastes of the particular consumers who are bidding. This flexibility is important because a common feature of the diverse items sold at auction is their uniqueness. No two oil paintings are the same even if painted by the same artist; Treasury bills sold today differ from those sold yesterday because of constantly changing information about fiscal and monetary policy as well as other economic factors. Auctions allow prices to reflect the unique aspects of goods being sold.

Auctions also differ from negotiated prices—they are less time-consuming than negotiations because the seller can compare the offers of competing buyers simultaneously rather than having to consider each offer one at a time. More importantly, once the rules of the auction are agreed on, sellers remain passive while the buyers determine the price; in other words, sellers cannot haggle with buyers as they can in negotiations. The seller's preferences only come into play when the rules of the auction are set. These auction rules serve as a commitment on the part of the seller to behave in a certain way; they also restrict the kind of offers buyers can make. So in auctions, both buyers and sellers are more constrained than in negotiations.

The rules of an auction also show exactly how a price will be determined so that demand equals supply. For example, the rules may say the winner must pay an amount equal to the highest bid. In other markets, where price adjustment is not so clear, economists have found it helpful to think about the adjustment in terms of auctions. For example, in a textbook competitive market, a hypothetical "Walrasian auctioneer" is thought to call out a price for each good, and then market participants tell him how much they demand and how much they want to supply of each good at that price. The "auctioneer" then adjusts prices—up for goods whose demand exceeds supply and down for goods whose supply exceeds demand—and the whole process continues until the market reaches equilibrium where supply equals demand, at which time trade occurs. No one believes such an auctioneer exists, but the apparatus gives economists a way of visualizing how prices move to their equilibrium levels.

Types of Auctions. Auctions are not all alike. Actually the word itself is something of a misnomer. *Auctio* means increase, but not all auctions involve calling out higher and higher bids. Auctions may take one of two basic forms, oral or sealed bid. In oral auctions, bidders hear one another's bids as they are made and can make counteroffers; each bidder knows how many others are bidding. In sealed bid auctions, bidders simultaneously submit one or more bids to the seller without revealing their bids to one another. In this case, the bidders do not necessarily know how many other bidders there are.

Two common types of oral auctions are the English and Dutch auctions. The *English* auction is the most common and well-known. The auctioneer raises the price until only one bidder remains—he wins the good at the price he has bid. In the *Dutch* auction (used to sell tulip bulbs in Holland and fish in Israel), the auctioneer calls out a high price and then continuously lowers the price until some bidder stops him and claims the good at that price.[3]

[3]Another type of oral auction, the double auction, is used on the New York Stock Exchange where many units of a good are auctioned at one time. Bids and offers are called out freely and anonymously and can be accepted immediately so that the market is continuously clearing.

In each of the different sealed bid auctions, the highest bidder wins, but the amount he has to pay differs. Consider a sealed bid auction of a plot of land and suppose three bids are received: $100,000, $99,000 and $98,000. In the *first price* auction, what you bid is what you pay if you win, so the bidder who submitted the $100,000 bid wins the land and pays $100,000. In the *second price* auction, again the highest bidder wins but he pays only the amount of the highest rejected bid, which is $99,000. Why might a seller use a second price auction? From this example, it appears he would always get a higher price by using the first price auction, but this is not true. The bidders know what kind of auction they are involved in and adjust their bids accordingly. Bidders tend to place higher bids in the second price auction than in the first price auction, so on the face of it, it is not clear which auction gives the seller the highest revenue. Still, the second price auction is rare.

Sealed bid auctions are also used to sell several units of a good at one time, such as tracts of land or Treasury bills. Though they appear more complex because multiple units and bids are involved, they are basically generalizations of the single unit first price and second price auctions. To see how these auctions work, suppose a seller auctions three identical plots of land, and he gets the following bids:

A submits 3 bids—$100,000 for one plot, $95,000 for an additional plot, and $92,000 for a third plot

B submits 3 bids—$99,000 for one plot, $98,500 for an additional plot, and $95,500 for a third plot

C submits 1 bid—$98,000 for one plot

The *discriminatory* sealed bid auction is like a first price auction: the highest bidders win and the winners pay what they bid. Each unit could be sold at a different price. In our example, the highest bids (and therefore, the prices paid) and the winners are: $100,000 from bidder A, $99,000 from bidder B, and $98,500 from bidder B again. Clearly, if two bidders win the same number of units they need not pay the same total amount for their winnings.[4]

In the *uniform* auction the units are all sold at the same price which is equal to the highest rejected bid, as in the second price auction. Since the winning three bids are $100,000, $99,000, and $98,500, the highest rejected bid is $98,000, so bidder A wins one plot of land and bidder B wins two plots, and they both pay $98,000 per plot.

During the 1960s a hot debate developed about whether U.S. Treasury bills should be sold in a uniform auction or a discriminatory auction. (See HOW TREASURY BILLS ARE AUCTIONED TODAY.) Proponents of the uniform price auction claimed that, because it was a simpler auction, bid preparation would be less costly, so more bidders would participate. This would lead to a larger volume of bills being sold, more efficient allocations of the bills, and higher bids. Proponents of the discriminatory auction claimed the government would obtain higher revenue via price discrimination.

If the type of auction had no effect on the way people bid, then the discriminatory auction would always yield the greater revenue. But buyers do bid differently depending on the rules of the auction. Economists are developing theoretical models of auction markets to examine the way bidders behave under various auction rules. Their results shed some light on why certain auctions are more common than others, what auction rules will generate the most revenue

[4]The Federal Reserve uses the discriminatory auction when it engages in short-term repurchase agreements with dealers. The auction sets the interest rate the Fed will earn on securities it purchases to temporarily increase the banking system's reserves. The Fed's outright purchases and sales for the System Account also usually occur through an auction with security dealers. See *The Federal Reserve System Purposes and Functions* (Washington D.C.: Board of Governors of the Federal Reserve System, 1984) pp. 38-43.

How Treasury Bills Are Auctioned Today

Each week the U.S. Treasury uses the discriminatory auction to sell Treasury bills to major buyers. On Tuesday the Treasury announces, via the Federal Reserve Banks, the amount of 91-day and 182-day bills it wishes to sell on the following Monday and invites tenders (bids) for specified amounts of these bills. Tenders are due by 1:00 p.m. Eastern time on the Monday after the announcement, and the Treasury usually publicizes the results later that afternoon. The bills are issued to the successful bidders on Thursday.

Two different types of bids can be submitted in the T-bill auction: competitive and noncompetitive. Competitive bidders include money market banks, dealers, and other institutional investors who buy large quantities of T-bills. The tenders they submit indicate the amount of bills they wish to purchase and the price they are willing to pay. They are permitted to submit more than one tender. Noncompetitive bidders are usually small or inexperienced bidders who indicate the amount of bills they want to purchase (up to $1,000,000) and agree to pay the quantity weighted average of the accepted competitive bids.

After all bids are in, first the Treasury sets aside the amount of bills requested by the noncompetitive bidders. The remainder is allocated among the competitive bidders, beginning with those who bid the highest price, until the total amount is issued. The price paid by the noncompetitive bidders can then be calculated based on the competitive bids that were accepted.[a]

The Treasury bill auction is more complicated than the standard discriminatory auction since the noncompetitive bids are satisfied in full. Consequently, when submitting their bids, the major buyers do not know the exact amount being auctioned to them. During 1987, an average of around $14 billion of Treasury bills were auctioned each week.

[a]See James F. Tucker, *Buying Treasury Securities at Federal Reserve Banks* (Federal Reserve Bank of Richmond, February 1985) for further details.

under different circumstances, and the crucial role of information.

PLAYING THE GAME: HOW ECONOMISTS MODEL AUCTIONS

In general, economists model the auction as a game with the bidders playing against each other. The point of the game is to win the object at the lowest possible price; each bidder devises a strategy with this in mind. The bidder's choice of strategy depends on what information the bidder has. Some information is available to all the players, like the rules of the particular auction being held. But each bidder also has *private information* about how she values the object—that is, information that only she knows. It is precisely because the bidders have some private information that sellers use an auction to set the price in the first place. If the seller knew each bidder's valuation he could just set the price of the object being sold at the highest valuation and not bother to hold the auction. The role of private information is crucial to understanding how auctions work. The assumptions made in the theoretical models about the nature of this private information range along a broad spectrum.

Independent Private Values. At one end of the spectrum, models assume that each bidder knows for certain how she values the object and that this information is totally private. The bidder's valuation of the object reflects her individual tastes; only she knows what that value is, and each bidder can have a different value. Suppose a painting is being auctioned to bidders who just want it because it is beautiful and not because they plan to sell it. (A museum might be this kind of bidder.) Then each bidder knows for certain what the painting is worth to herself but not to the other bidders, and what other bidders know about the painting will not affect her own valuation—these bidders are said to have *private values*.

Even though the bidders have private values,

each would like to know how the other bidders value the item (that is, their private information), because this would reveal something about how they are likely to bid. When the bidders' values are *independent*, then the value one bidder places on the painting is not systematically related to the values the others place on the object. In this case, a bidder's own valuation of the painting tells her nothing about the other bidders' valuations and so nothing about how they will bid.

Common Values. Models at the other end of the spectrum assume that the object being auctioned is worth the same to all bidders, but they are unsure of this value. Bidders have private information that tells them something about this true market value of the object, although not enough to be certain. For example, when the government announces a lease sale of oil and gas deposits on offshore public lands, it lets firms use seismic surveys and off-site drilling to gather information about the tracts. So different potential buyers may have different information about the market value of the tracts when it comes time to bid. The right to extract the deposits is worth the same thing to each bidder—the market value of the oil or gas actually in the land—so the bidders have common values. At the time of bidding no bidder knows this value for sure and each makes an estimate of the value based on his private information.

As in the private values model, a bidder in the common values model would like to find out what private information the other bidders have, because it would tell him something about how they are likely to bid. But, unlike the private values model, finding out their private information would also reveal something more about the likely market value of the object, which is precisely the value he is trying to estimate. Learning about another bidder's estimate, which reflects that bidder's private information, will affect a bidder's own estimate of the object's market value. Unlike the private values model, a bidder's beliefs about the value of the object can change during the course of an auction as he sees how other bidders are bidding.

Because the bidders in the common values model are unsure about the true value of the object, they are subject to the *"winner's curse."* Suppose one bidder estimates an antique chair is worth $500 based on his private information, but all the other bidders estimate its value at no more than $400. If that one bidder offers $500, he will win the chair. But by bidding his estimate, the winner is cursed! Winning conveys the message that every other bidder made a lower estimate of the chair's value, and so, on average, the winner who has bid his estimate will pay more than the chair is worth on the open market.

Bidders can avoid the winner's curse by bidding less than they think the object is worth. When there are fewer bidders, a bidder can shade down his bid more without affecting his probability of winning, because there is less chance that someone else's bid is just below his. So the seller can expect a lower price when there are fewer bidders.

Models and Reality. The independent private values model and the common values model describe extreme situations. Most real life situations are not so simple. For example, in an art auction, many bidders care about the painting's resale value as well as its personal value. Therefore, their values are neither private nor independent. Likewise, in the mineral rights auction, the value of the minerals is related to how efficiently the firm extracts them—the amount of recoverable minerals may differ for each firm bidding and so the value of the extraction rights to each firm is no longer a common value.[5]

[5]Although most theoretical research has concentrated on the polar case models, Paul Milgrom and Robert Weber have analyzed a model that includes the independent private values model and the common values model as special cases. See Paul Milgrom and Robert Weber, "A Theory of Auctions...."

A SELLER NEEDS TO KNOW THE BIDDERS' STRATEGIES...

When a seller gets ready to put his antique car or his plot of land up for auction, he has to decide which kind of auction can be expected to give him the highest price, and this will depend on how bidders behave. Analyses of theoretical models of auctions show that several factors will affect the expected price, such as whether bidders are more likely to have private values or common values, and how willing the bidders are to risk not winning the object.

Dutch and First Price Auctions. In theory, bidders behave the same way in the Dutch auction, where prices are called out in descending order, as they do in the sealed bid first price auction. So it does not matter which of these two types the seller chooses, regardless of whether the situation is an independent private values one or a common values one.[6]

A bidder follows the same strategy in the Dutch and the first price auctions because in both auctions he makes the same decision based on the same information. He knows that if he wins he has to pay what he bid, and that he wins only if he bids higher than everyone else. But he has to decide what to bid without knowing what the others are going to do. It might seem that the auctions should differ, since a bidder learns something about the other bidders' valuations during the course of the Dutch auction but not during the first price auction. But the kind of information he learns had already been incorporated into the strategy he chose at the beginning of the Dutch auction, and it is the same information he uses when choosing his strategy in the first price auction. In the Dutch auction, a bidder selects a cutoff price at which he will claim the object so long as no one else has already claimed it. As the auctioneer lowers the price, the bidder hears prices he knows are higher than other bidders' cutoff prices. But this information does not lead him to change his own cutoff price because he chose it understanding that he wins only if the other bidders have a lower cutoff value. Likewise, in the sealed bid first price auction, he selects a price knowing that it will win the object only if others have selected a lower price. Therefore, in both the Dutch auction and the first price auction, all the bidders will have the same strategy. They shade down their bids slightly below their valuations since in these auctions winners pay what they bid.

English and Second Price Auctions. The choice between the English and second price auction, on the other hand, does depend on whether the bidders know their own private values or bidders are unsure about the single common value of the item. In a situation when bidders have independent private values, both auctions yield the same outcome. In the English auction, the bidder keeps raising his bid until the price equals the value of the object to him, or until he is the last remaining bidder. Once the price equals the second highest valuation, the bidder with the second highest valuation stops bidding. The remaining bidder (who has the highest valuation) can claim the object by bidding only very slightly more than the second highest valuation. In the second price auction, the bidder simply submits a bid equal to what the object is worth to himself, since if he wins, what he pays is beyond his control anyway. Therefore, in either auction when there are independent private values, the winner is the bidder with the highest valuation and the price he pays is equal to the second highest valuation.

In a common values situation, where bidders are unsure of the value of the object being auctioned, the English and second price auctions no longer lead to the same outcome. This is because in the English auction a bidder gains two types of useful information by observing the bids of others (information he would not know at the start of the auction). He sees how many bidders

[6]However, Paul Milgrom, "The Economics...," p. 274, reports that Cox, Roberson, and Smith (in press) have experimental evidence that seems to refute this.

have fallen out of the auction (since they have lower valuations than the price being called) and he sees at what prices these bidders have fallen out. If a bidder had a reasonably high estimate of the value to start with, he gains confidence in this estimate as the bids go up, especially if many people are still in the bidding; this weakens the winner's curse and allows more aggressive bidding than in the sealed bid auction. So the price paid is likely to be higher in an English auction than in a sealed bid second price auction.

...SO HE CAN CHOOSE THE AUCTION WITH THE HIGHEST EXPECTED REVENUE.

The seller now knows that regardless of the type of information bidders have (independent private values or common values), Dutch auctions and first price auctions are expected to generate the same revenue. He also knows that with independent private values, English and second price auctions yield the same expected revenue, but with common values, the English auction is expected to be better. (See EXPECTED REVENUE DEPENDS ON TYPE OF VALUES...)

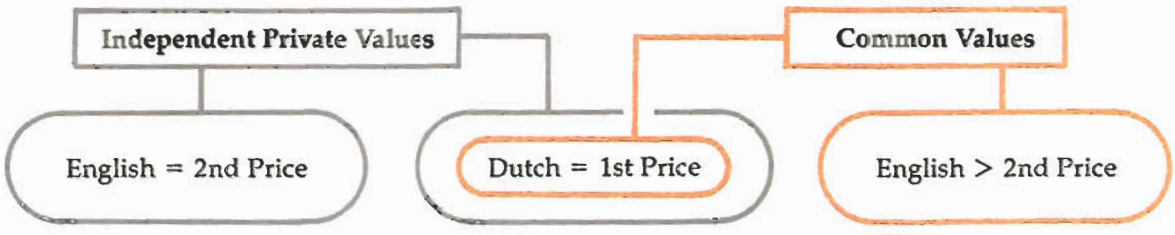
What about the Dutch and first price auction as compared with the English and second price auction? One important factor in determining which auction yields the highest revenue is how the bidders feel about the risk of losing. While each bidder in an auction would like to win, *risk averse* bidders tend to up their bids so they will be more likely to win, while *risk neutral* bidders do not.

Risk and Independent Values. In fact, in the independent private values model when all bidders are risk neutral, the Dutch and first price auctions give the seller the same revenue, on average, as the English and second price auctions. That is, while the prices are not always exactly the same, they are the same on average over a series of auctions. (This result is not obvious and remained obscure long after being proved.[7])

If, on the other hand, bidders are risk averse, then the first price auction (and therefore the Dutch) gives greater expected revenue than the second price and English auctions. In either the second price auction or English auction, risk averse bidders find it best to bid the same way they would if they were risk neutral. But in the first price or Dutch auction, risk averse bidders find it better to bid higher than they would have if they were risk neutral, as a kind of insurance against losing. (They still bid less than their valuations.) Since with risk neutral bidders, the expected revenue was the same in the four auctions, it follows that with risk averse bidders, the

[7]For our more technical readers: Bidders can be thought of as choosing, through their actions, a probability of winning and a corresponding expected payment. The revenue equivalence result hinges on the fact that, in equilibrium, the probability a bidder with a given valuation wins, is the same across all auctions in which the winning bidder has the highest valuation. In the independent private values model, all four auctions—Dutch, English, first price, and second price—have this trait. See Paul Milgrom and Robert Weber, "A Theory of Auctions...," pp. 1092-1093.

Expected Revenue Depends on Type of Values...



first price and Dutch auctions yield greater expected revenue than the second price and English auctions.

Risk and Common Values. Now suppose once again that bidders are risk neutral but that common values describe the situation.[8] In this case, the English auction yields the highest expected price and revenue, then the second price auction, and finally the Dutch and first price auctions. This may explain the popularity of the English auction.

We can rank these auctions using the fact that the more the price paid by the winning bidder is linked to the value estimates of the other bidders, the higher this price is expected to be. The expected price in the English auction is dependent on all the non-winners' value estimates, since the winner observes the prices at which all the other bidders have dropped out, and bases her winning bid on this information. In the second price auction, the winning price is linked to only one other value estimate—the second highest estimate—since the winning bidder must pay a price equal to the second highest submitted bid. So the expected revenue in a second price auction is less than that in an English auction. In the first price and Dutch auctions, the winning bid is not linked to any other bidder's value estimate, and these auctions yield the lowest expected revenue.

Unfortunately, if bidders are risk averse, we can no longer predict which auction yields the highest expected revenue in situations with common values or dependent values. While we know that the expected revenue from the Dutch and first price auctions is the same, and the expected revenue from the English auction surpasses that of the second price auction, the complete ranking depends on the degree of risk aversion of the bidders and on how correlated their valuations are. (See ...AND ON BIDDERS' RISK CHARACTERISTICS.)

Implications for Treasury Bill Auctions. These revenue results shed some new light on whether the U.S. should continue to use a discriminatory auction to sell Treasury bills. If the T-bill auction could be described by an independent private values model, then if bidders are risk neutral it does not matter which type of auction is used, and if bidders are risk averse the government earns higher revenue, on average, using the discriminatory auction (which is like a first price auction). But the T-bill auction seems to be more of a common values situation since

[8]Actually, all that is needed is that the bidders' valuations be dependent. That is, if a bidder places a high value on the object, she knows the other bidders are likely to place a high value on it too. Common values is the extreme case since all bidders are trying to estimate a single common value. (The estimates conditional on the true value may be independent, however.)

...And on Bidders' Risk Characteristics

	Independent Private Values			Common Values		
Risk Neutral Bidders	Dutch = 1st Price	=	English = 2nd Price	English > 2nd Price	>	Dutch = 1st Price
Risk Averse Bidders	Dutch = 1st Price	>	English = 2nd Price	English > 2nd Price	?	Dutch = 1st Price

buyers are interested in the market value of the bills; so if bidders are risk neutral, the government would be better off switching to the uniform auction (which is like a second price auction). If, however, bidders are risk averse, we cannot say which auction would yield the higher expected revenue. Empirical work has compared the revenue generated by the uniform price auction which was used to sell long-term bonds in the 1970s and the discriminatory auction which is used to sell short-term and medium-term bonds.[9] The results indicate that the uniform auctions tended to yield higher revenue. This is consistent with theory when bidders have common (or dependent) values and are risk neutral.

In sum, what these results tell us is that before a seller can decide on which auction to use, he needs to find out in which situation he is likely to be. Are bidders risk averse or risk neutral? Does the situation look more like an independent private values one or a common values one? Which type of situation it is will depend on the kind of information the bidders have.

THERE'S STILL A LOT TO LEARN: THE GAVEL HASN'T FALLEN YET

Economists are just beginning to address some of the interesting questions about auctions. For example, although we know (at least in the simple models) the buyers' best strategies in an auction, we know less about when the seller will choose an auction as opposed to some other method to set the price. One reason the auction is used in a wide variety of situations is that it is efficient—the winner values the object more than any of the other bidders (and more than the seller), and he pays more than others would have paid. This means that after someone wins the object in an auction he will not be able to sell the object at a profit to someone else who participated in the auction. And the person who held the auction will not be told by a bidder afterward that she would have been willing to pay more than the winner did. So from the seller's point of view the auction can give him the highest price he can expect to receive for the object.[10]

Another area of active research concerns the seller's policy of revealing information about the object he is auctioning. Whether the seller benefits from such a policy depends upon the nature of his information. In some cases, the seller would gain, on average, from telling all the bidders his information since this would decrease the advantage some of the bidders have over others. By revealing his information the seller can weaken the winner's curse, allowing bidders to bid more aggressively. This may explain why auction houses often reveal appraisals of the objects they sell.[11] But recent work shows that adopting the policy of telling *all* kinds of information is not always in the best interest of the seller.[12] And, in fact, some government agencies conceal information about the number of firms they have invited to submit bids in their auctions.[13]

In general, most of the models studied so far have been simplifications of real life situations. Even these simple models have been difficult to analyze. But the models are becoming more realistic. Auctions with multiple buyers and sellers, like the double auction, are being

[9]See Paul Milgrom and Robert Weber, "A Theory of Auctions...," p. 1094.

[10]Another result that explains the popularity of auctions is that a seller in a poor bargaining position compared to the buyers can do almost as well as a seller in a strong bargaining position by conducting an auction. Also, a seller in a strong bargaining position sometimes will be better off selling an object by one of the standard auctions (like sealed bid, or English) than by any other method. These results are from Paul Milgrom, "Auction Theory," in Truman F. Bewley, ed., *Advances in Economic Theory* (Cambridge: Cambridge University Press, 1987), pp. 26-27.

[11]Paul Milgrom, "The Economics...," p. 287 discusses this.

[12]See Steven Matthews, "Comparing Auctions for Risk Averse Buyers: A Buyer's Point of View," *Econometrica*, 55 (May 1987), pp. 633-646.

[13]See R. Preston McAfee and John McMillan in "Auctions and Bidding," *Journal of Economic Literature*, 25 (June 1987), p. 720.

studied, as are models that assume bidders are able to collude to keep the price down. In oil and timber rights auctions the same bidders may meet again and again and so should learn more and more about their competitors—this repetition could facilitate collusion. The research that has been done suggests that some types of auctions are more susceptible to collusion than others. In one model, it is shown that collusion is easier in the English auction than in a sealed bid auction. This may explain why industrial firms, whose pool of bidders is often the same time and time again, usually solicit sealed bids.[14]

A different avenue of research being pursued involves testing the predictions of the theoretical models. Data from actual auctions are being analyzed, as are data collected from laboratory experiments. (See Herb Taylor's article in this *Business Review*.) We can expect both empirical and theoretical advances in the study of auctions in the future.

[14]This model is developed by Paul R. Milgrom in "Auction Theory."