

CHAPTER 17

AUCTIONS

Auctions are one of the oldest form of markets, dating back to at least 500 BC. Today, all sorts of commodities, from used computers to fresh flowers, are sold using auctions.

Economists became interested in auctions in the early 1970s when the OPEC oil cartel raised the price of oil. The U.S. Department of the Interior decided to hold auctions to sell the right to drill in coastal areas that were expected to contain vast amounts of oil. The government asked economists how to design these auctions, and private firms hired economists as consultants to help them design a bidding strategy. This effort prompted considerable research in auction design and strategy.

More recently, the Federal Communications Commission (FCC) decided to auction off parts of the radio spectrum for use by cellular phones, personal digital assistants, and other communication devices. Again, economists played a major role in the design of both the auctions and the strategies used by the bidders. These auctions were hailed as very successful public policy, resulting in revenues to the U.S. government of over twenty-three billion dollars to date.

Other countries have also used auctions for privatization projects. For example, Australia sold off several government-owned electricity plants, and New Zealand auctioned off parts of its state-owned telephone system.

Consumer-oriented auctions have also experienced something of a renaissance on the Internet. There are hundreds of auctions on the Internet, selling collectibles, computer equipment, travel services, and other items. OnSale claims to be the largest, reporting over forty-one million dollars worth of merchandise sold in 1997.

17.1 Classification of Auctions

The economic classification of auctions involves two considerations: first, what is the nature of the good that is being auctioned, and second, what are the rules of bidding? With respect to the nature of the good, economists distinguish between **private-value auctions** and **common-value auctions**.

In a private-value auction, each participant has a potentially different value for the good in question. A particular piece of art may be worth \$500 to one collector, \$200 to another, and \$50 to yet another, depending on their taste. In a common-value auction, the good in question is worth essentially the same amount to every bidder, although the bidders may have different estimates of that common value. The auction for off-shore drilling rights described above had this characteristic: a given tract either had a certain amount of oil or not. Different oil companies may have had different estimates about how much oil was there, based on the outcomes of their geological surveys, but the oil had the same market value regardless of who won the auction.

We will spend most of the time in this chapter discussing private-value auctions, since they are the most familiar case. At the end of the chapter, we will describe some of the features of common-value auctions.

Bidding Rules

The most prevalent form of bidding structure for an auction is the **English auction**. The auctioneer starts with a **reserve price**, which is the lowest price at which the seller of the good will part with it.¹ Bidders successively offer higher prices; generally each bid must exceed the previous bid by some minimal **bid increment**. When no participant is willing to increase the bid further, the item is awarded to the highest bidder.

Another form of auction is known as a **Dutch auction**, due to its use in the Netherlands for selling cheese and fresh flowers. In this case the auctioneer starts with a high price and gradually lowers it by steps until someone is willing to buy the item. In practice, the “auctioneer” is often a mechanical device like a dial with a pointer which rotates to lower and

¹ See the footnote about “reservation price” in Chapter 6.

lower values as the auction progresses. Dutch auctions can proceed very rapidly, which is one of their chief virtues.

Yet a third form of auctions is a **sealed-bid auction**. In this type of auction, each bidder writes down a bid on a slip of paper and seals it in an envelope. The envelopes are collected and opened, and the good is awarded to the person with the highest bid who then pays the auctioneer the amount that he or she bid. If there is a reserve price, and all bids are lower than the reserve price, then no one may receive the item.

Sealed-bid auctions are commonly used for construction work. The person who wants the construction work done requests bids from several contractors with the understanding that the job will be awarded to the contractor with the lowest bid.

Finally, we consider a variant on the sealed bid-auction that is known as the **philatelist auction** or **Vickrey auction**. The first name is due to the fact that this auction form was originally used by stamp collectors; the second name is in honor of William Vickrey, who received the 1996 Nobel prize for his pioneering work in analyzing auctions. The Vickrey auction is like the sealed-bid auction, with one critical difference: the good is awarded to the highest bidder, but at the *second-highest* price. In other words, the person who bids the most gets the good, but he or she only has to pay the bid made by the second-highest bidder. Though at first this sounds like a rather strange auction form, we will see below that it has some very nice properties.

17.2 Auction Design

Let us suppose that we have a single item to auction off and that there are n bidders with (private) values $v_1, \dots, v_n$. For simplicity, we assume that the values are all positive and that the seller has a zero value. Our goal is to choose an auction form to sell this item.

This is a special case of an **economic mechanism design** problem. In the case of the auction there are two natural goals that we might have in mind:

- **Pareto efficiency.** Design an auction that results in a Pareto efficient outcome.
- **Profit maximization.** Design an auction that yields the highest expected profit to the seller.

Profit maximization seems pretty straightforward, but what does Pareto efficiency mean in this context? It is not hard to see that Pareto efficiency requires that the good be assigned to the person with the highest value. To see this, suppose that person 1 has the highest value and person 2 has

some lower value for the good. If person 2 receives the good, then there is an easy way to make both 1 and 2 better off: transfer the good from person 2 to person 1 and have person 1 pay person 2 some price p that lies between v_1 and v_2 . This shows that assigning the good to anyone but the person who has the highest value cannot be Pareto efficient.

If the seller knows the values $v_1, \dots, v_n$ the auction design problem is pretty trivial. In the case of profit maximization, the seller should just award the item to the person with the highest value and charge him or her that value. If the desired goal is Pareto efficiency, the person with the highest value should still get the good, but the price paid could be any amount between that person's value and zero, since the distribution of the surplus does not matter for Pareto efficiency.

The more interesting case is when the seller does not know the buyers' values. How can one achieve efficiency or profit maximization in this case?

First consider Pareto efficiency. It is not hard to see that an English auction achieves the desired outcome: the person with the highest value will end up with the good. It requires only a little more thought to determine the price that this person will pay: it will be the value of the *second-highest* bidder plus, perhaps, the minimal bid increment.

Think of a specific case where the highest value is, say \$100, the second-highest value is \$80, and the bid increment is, say, \$5. Then the person with the \$100 valuation would be willing to bid \$85, while the person with the \$80 value would not. Just as we claimed, the person with the highest valuation gets the good, at the second highest price (plus, perhaps, the bid increment). (We keep saying "perhaps" since if both players bid \$80 there would be a tie and the exact outcome would depend on the rule used for tie-breaking.)

What about profit maximization? This case turns out to be more difficult to analyze since it depends on the *beliefs* that the seller has about the buyers' valuations. To see how this works, suppose that there are just two bidders either of whom could have a value of \$10 or \$100 for the item in question. Assume these two cases are equally likely, so that there are four equally probable arrangements for the values of bidders 1 and 2: (10,10), (10,100), (100,10), (100,100). Finally, suppose that the minimal bid increment is \$1 and that ties are resolved by flipping a coin.

In this example, the winning bids in the four cases described above will be (10,11,11,100) and the bidder with the highest value will always get the good. The expected revenue to the seller is $\$33 = \frac{1}{4}(10 + 11 + 11 + 100)$.

Can the seller do better than this? Yes, if he sets an appropriate reservation price. In this case, the profit-maximizing reservation price is \$100. Three-quarters of the time, the seller will sell the item for this price, and one-quarter of the time there will be no winning bid. This yields an expected revenue of \$75, much higher than the expected revenue yielded by the English auction with no reservation price.

Note that this policy is *not* Pareto efficient, since one-quarter of the time

no one gets the good. This is analogous to the deadweight loss of monopoly and arises for exactly the same reason.

The addition of the reservation price is very important if you are interested in profit maximization. In 1990, the New Zealand government auctioned off some of the spectrum for use by radio, television, and cellular telephones, using a Vickrey auction. In one case, the winning bid was NZ\$100,000, but the second-highest bid was only NZ\$6! This auction may have led to a Pareto efficient outcome, but it was certainly not revenue maximizing!

We have seen that the English auction with a zero reservation price guarantees Pareto efficiency. What about the Dutch auction? The answer here is not necessarily. To see this, consider a case with two bidders who have values of \$100 and \$80. If the high-value person believes (erroneously!) that the second-highest value is \$70, he or she would plan to wait until the auctioneer reached, say, \$75 before bidding. But, by then, it would be too late—the person with the second-highest value would have already bought the good at \$80. In general, there is no guarantee that the good will be awarded to the person with the highest valuation.

The same holds for the case of a sealed-bid auction. The optimal bid for each of the agents depends on their *beliefs* about the values of the other agents. If those beliefs are inaccurate, the good may easily end up being awarded to someone who does not have the highest valuation.²

Finally, we consider the Vickrey auction—the variant on the sealed-bid auction where the highest bidder gets the item, but only has to pay the second-highest price.

First we observe that *if* everyone bids their true value for the good in question, the item will end up being awarded to the person with the highest value, who will pay a price equal to that of the person with the second-highest value. This is essentially the same as the outcome of the English auction (up to the bid increment, which can be arbitrarily small).

But is it optimal to state your true value in a Vickrey auction? We saw that for the standard sealed-bid auction, this is not generally the case. But the Vickrey auction is different: the surprising answer is that it is always in each player's interest to write down their true value.

To see why, let us look at the special case of two bidders, who have values v_1 and v_2 and write down bids of b_1 and b_2 . The expected payoff to bidder 1 is:

$$\text{Prob}(b_1 \geq b_2)[v_1 - b_2],$$

² On the other hand, if all players' beliefs are accurate, on average, and all bidders play optimally, the various auction forms described above turn out to yield the same allocation and the same expected price in equilibrium. For a detailed analysis, see P. Milgrom, "Auctions and Bidding: a Primer," *Journal of Economic Perspectives*, **3**(3), 1989, 3–22, and P. Klemperer, "Auction Theory: A Guide to the Literature," *Economic Surveys*, **13**(3), 1999, 227–286.

where “Prob” stands for “probability.”

The first term in this expression is the probability that bidder 1 has the highest bid; the second term is the consumer surplus that bidder 1 enjoys if he wins. (If $b_1 < b_2$, then bidder 1 gets a surplus of 0, so there is no need to consider the term containing $\text{Prob}(b_1 \leq b_2)$.)

Suppose that $v_1 > b_2$. Then bidder 1 wants to make the probability of winning as large as possible, which he can do by setting $b_1 = v_1$. Suppose, on the other hand, that $v_1 < b_2$. Then bidder 1 wants to make the probability of winning as small as possible, which he can do by setting $b_1 = v_1$. In either case, an optimal strategy for bidder 1 is to set his bid equal to his true value! Honesty is the best policy . . . at least in a Vickrey auction!

The interesting feature of the Vickrey auction is that it achieves essentially the same outcome as an English auction, but without the iteration. This is apparently why it was used by stamp collectors. They sold stamps at their conventions using English auctions and via their newsletters using sealed-bid auctions. Someone noticed that the sealed-bid auction would mimic the outcome of the English auctions if they used the second-highest bid rule. But it was left to Vickrey to conduct the full-fledged analysis of the philatelist auction and show that truth-telling was the optimal strategy and that the philatelist auction was equivalent to the English auction.

17.3 Other Auction Forms

The Vickrey auction was thought to be only of limited interest until online auctions became popular. The world’s largest online auction house, eBay, claims to have almost 30 million registered users who, in 2000, traded \$5 billion worth of merchandise.

Auctions run by eBay last for several days, or even weeks, and it is inconvenient for users to monitor the auction process continually. In order to avoid constant monitoring, eBay introduced an automated **bidding agent**, which they call a **proxy bidder**. Users tell their bidding agent the most they are willing to pay for an item and an initial bid. As the bidding progresses, the agent automatically increases a participant’s bid by the minimal bid increment when necessary, as long as this doesn’t raise the participant’s bid over his or her maximum.

Essentially this is a Vickrey auction: each user reveals to their bidding agent the maximum price he or she is willing to pay. In theory, the participant who enters the highest bid will win the item but will only have to pay the second-highest bid (plus a minimal bid increment to break the tie.) According to the analysis in the text, each bidder has an incentive to reveal his or her true value for the item being sold.

In practice, bidder behavior is a bit different than that predicted by the Vickrey model. Often bidders wait until close to the end of the auction to enter their bids. This behavior appears to be for two distinct reasons: a

reluctance to reveal interest too early in the game, and the hope to snatch up a bargain in an auction with few participants. Nevertheless, the bidding agent model seems to serve users very well. The Vickrey auction, which was once thought to be only of theoretical interest, is now the preferred method of bidding for the world's largest online auction house!

There are even more exotic auction designs in use. One peculiar example is the **escalation auction**. In this type of auction, the highest bidder wins the item, but the highest and the second-highest bidders *both* have to pay the amount they bid.

Suppose, for example, that you auction off 1 dollar to a number of bidders under the escalation auction rules. Typically a few people bid 10 or 15 cents, but eventually most of the bidders drop out. When the highest bid approaches 1 dollar, the remaining bidders begin to catch on to the problem they face. If one has bid 90 cents, and the other 85 cents, the low bidder realizes that if he stays put, he will pay 85 cents and get nothing but, if he escalates to 95 cents, he will walk away with a nickel.

But once he has done this, the bidder who was at 90 cents can reason the same way. In fact, it is in her interest to bid *over* a dollar. If, for example, she bids \$1.05 (and wins), she will lose only 5 cents rather than 90 cents! It's not uncommon to see the winning bid end up at \$5 or \$6.

A somewhat related auction is the **everyone pays auction**. Think of a crooked politician who announces that he will sell his vote under the following conditions: all the lobbyists contribute to his campaign, but he will vote for the appropriations favored by the highest contributor. This is essentially an auction where everyone pays but only the high bidder gets what she wants!

EXAMPLE: Late Bidding on eBay

According to standard auction theory eBay's proxy bidder should induce people to bid their true value for an item. The highest bidder wins at (essentially) the second highest bid, just as in a Vickrey auction. But it doesn't work quite like that in practice. In many auctions, participants wait until virtually the last minute to place their bids. In one study, 37 percent of the auctions had bids in the last minute and 12 percent had bids in the last 10 seconds. Why do we see so many "late bids"?

There are at least two theories to explain this phenomenon. Patrick Bajari and Ali Hortacısu, two auction experts, argue that for certain sorts of auctions, people don't want to bid early to avoid driving up the selling price. eBay typically displays the bidder identification and actual bids (not the maximum bids) for items being sold. If you are an expert on rare stamps, with a well-known eBay member name, you may want to hold back placing your bid so as not to reveal that you are interested in a particular stamp.

This explanation makes a lot of sense for collectibles such as stamps and coins, but late bidding also occurs in auctions for generic items, such as computer parts. Al Roth and Axel Ockenfels suggest that late bidding is a way to avoiding bidding wars.

Suppose that you and someone else are bidding for a Pez dispenser with a seller's reserve price of \$2. It happens that you each value the dispenser at \$10. If you both bid early, stating your true maximum value of \$10, then even if the tie is resolved in your favor you end up paying \$10—since that is also the other bidder's maximum value. You may “win” but you don't get any consumer surplus!

Alternatively, suppose that each of you waits until the auction is almost over and then bids \$10 in the last possible seconds of the auction. (At eBay, this is called “sniping.”) In this case, there's a good chance that one of the bids won't get through, so the winner ends up paying only the seller's reserve price of \$2.

Bidding high at the last minute introduces some randomness into the outcome. One of the players gets a great deal and the other gets nothing. But that's not necessarily so bad: if they both bid early, one of the players ends up paying his full value and the other gets nothing.

In this analysis, the late bidding is a form of “implicit collusion.” By waiting to bid, and allowing chance to play a role, bidders can end up doing substantially better on average than they do by bidding early.

EXAMPLE: Online Ad Auctions

Google and Yahoo are two popular search engines that make money by selling ads triggered by search queries. When someone searches for, say, “trips to Hawaii,” she will retrieve search results that describe various aspects of Hawaii along with some brief ads offering to sell airline tickets, hotel rooms, rental cars, and other items that are related to “trips to Hawaii.” When someone clicks on one of these ads, the advertiser pays the search engine some amount of money for the “lead.”

The amount that an advertiser has to pay is determined by a **position auction**. Each advertiser states a maximum bid per click that they are willing to pay. The highest bidder gets the most prominent position, the second highest bidder gets the second-best position, and so on down to the last advertiser on the page, who pays the bid of the highest-bidding advertiser whose ad isn't shown. If there are no other ads to be shown, the last advertiser pays a reserve price set by the search engine.

As with the Vickrey auction, the highest bidder pays the second highest bid, the second highest bidder pays the third highest bid, and so on. Originally, the search engines thought about charging each person his actual bid. But they quickly realized that if they did so, advertisers would sign on to the system all the time to check the prices, and reduce their bids so

that they didn't have to pay more than they had to pay to occupy their preferred position. Google describes their auction in terms of an "AdWords Discounter," which is a bit like the proxy bidder on eBay. Basically, the AdWords Discounter adjusts your bid so you never have to pay more than you have to pay to be in a given position.

There are some complications. For example, in the Google auction, the position is determined not only by the bid, but also by an estimate of the ad's quality and relevance to the query.

Interestingly, unlike the Vickrey auction, it is not an equilibrium to bid your true value in this form of position auction. Suppose you are in position 3. The relevant calculation is to compare the *incremental* value you would get from bidding more—the extra clicks you would get from being in a more prominent position—to the additional cost you would have to pay to be in that higher position. Similarly, you could also look at the amount of money you would save by being in a lower position and compare that to the value of the lost clicks.

In equilibrium, each bidder prefers the position it occupies to the other possible positions. If each player follows this strategy, the auction will assign those advertisers with the highest value per click to the most prominent positions.

17.4 Problems with Auctions

We've seen above that English auctions (or Vickrey auctions) have the desirable property of achieving Pareto efficient outcomes. This makes them attractive candidates for resource allocation mechanisms. In fact, most of the airwave auctions used by the FCC were variants on the English auction.

But English auctions are not perfect. They are still susceptible to collusion. The example of pooling in auction markets, described in Chapter 24, shows how antique dealers in Philadelphia colluded on their bidding strategies in auctions.

There are also various ways to manipulate the outcome of auctions. In the analysis described earlier, we assumed that a bid *committed* the bidder to pay. However, some auction designs allow bidders to drop out once the winning bids are revealed. Such an option allows for manipulation. For example, in 1993 the Australian government auctioned off licenses for satellite-television services using a standard sealed-bid auction. The winning bid for one of the licenses, A\$212 million, was made by a company called Ucom. Once the government announced Ucom had won, they proceeded to default on their bid, leaving the government to award the license to the second-highest bidder—which was also Ucom! They defaulted on this bid as well; four months later, after several more defaults, they paid A\$117 million for the license, which was A\$95 million less than their initial winning bid! The license ended up being awarded to the highest bidder at

the second-highest price—but the poorly designed auction caused at least a year delay in bringing pay-TV to Australia.³

17.5 The Winner's Curse

We turn now to the examination of **common-value auctions**, where the good that is being awarded has the *same* value to all bidders. However, each of the bidders may have different estimates of that value. To emphasize this, let us write the (estimated) value of bidder i as $v + \epsilon_i$ where v is the true, common value and ϵ_i is the “error term” associated with bidder i 's estimate.

Let's examine a sealed-bid auction in this framework. What bid should bidder i place? To develop some intuition, let's see what happens if each bidder bids their estimated value. In this case, the person with the highest value of ϵ_i , ϵ_{max} , gets the good. But as long as $\epsilon_{max} > 0$, this person is paying more than v , the true value of the good. This is the so-called **Winner's Curse**. If you win the auction, it is because you have overestimated the value of the good being sold. In other words, you have won only because you were too optimistic!

The *optimal* strategy in a common-value auction like this is to bid less than your estimated value—and the more bidders there are, the lower you want your own bid to be. Think about it: if you are the highest bidder out of five bidders you may be overly optimistic, but if you are the highest bidder out of twenty bidders you must be *super* optimistic. The more bidders there are, the more humble you should be about your own estimates of the “true value” of the good in question.

The Winner's Curse seemed to be operating in the FCC's May 1996 spectrum auction for personal communications services. The largest bidder in that auction, NextWave Personal Communications Inc., bid \$4.2 billion for sixty-three licenses, winning them all. However, in January 1998 the company filed for Chapter Eleven bankruptcy protection, after finding itself unable to pay its bills.

Summary

1. Auctions have been used for thousands of years to sell things.
2. If each bidder's value is independent of the other bidders, the auction is said to be a private-value auction. If the value of the item being sold is

³ See John McMillan, “Selling Spectrum Rights,” *Journal of Economic Perspectives*, 8(3), 145–152, for details of this story and how its lessons were incorporated into the design of the U.S. spectrum auction. This article also describes the New Zealand example mentioned earlier.

essentially the same for everyone, the auction is said to be a common-value auction.

3. Common auction forms are the English auction, the Dutch auction, the sealed-bid auction, and the Vickrey auction.

4. English auctions and Vickrey auctions have the desirable property that their outcomes are Pareto efficient.

5. Profit-maximizing auctions typically require a strategic choice of the reservation price.

6. Despite their advantages as market mechanisms, auctions are vulnerable to collusion and other forms of strategic behavior.

REVIEW QUESTIONS

1. Consider an auction of antique quilts to collectors. Is this a private-value or a common-value auction?

2. Suppose that there are only two bidders with values of \$8 and \$10 for an item with a bid increment of \$1. What should the reservation price be in a profit-maximizing English auction?

3. Suppose that we have two copies of *Intermediate Microeconomics* to sell to three (enthusiastic) students. How can we use a sealed-bid auction that will guarantee that the bidders with the two highest values get the books?

4. Consider the Ucom example in the text. Was the auction design efficient? Did it maximize profits?

5. A game theorist fills a jar with pennies and auctions it off on the first day of class using an English auction. Is this a private-value or a common-value auction? Do you think the winning bidder usually makes a profit?