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Authors

French, Kenneth R.
McCormick, Robert E.

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SUNK COSTS AND COMPETITIVE BIDDING

Kenneth R. French
Graduate School of Management
University of California, Los Angeles, 90024

Robert E. McCormick
Clemson University
Clemson, South Carolina

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Kenneth R. French
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1. Introduction

Sealed-bid auctions determine the allocation of many resources. For example, construction contracts, defense contracts, and offshore oil leases are often awarded on the basis of competitive bids. Although a number of papers have examined the optimal bidding strategies for these auctions, very little attention has been paid to the question of how firms recover pre-bid costs.¹

Consider a hypothetical sealed-bid auction in which ten firms are competing for the right to explore and develop an offshore oil field. Each of these firms has spent \$500,000 to estimate the value of the field and to prepare its bid. Suppose this investigation reveals that the tract is worth approximately \$20 million. What will the winning bid be? If sunk costs do not matter, competition dictates that the winner must bid \$20 million. If the winner is to recover his costs, the maximum offer will be \$19.5 million. Finally, long-run industry equilibrium considerations suggest that the highest bid will be \$15 million (\$20 million minus the total bid preparation costs of \$5 million).

A more common bidding situation involves construction. In anticipation of its move from Rochester, New York, to Stamford, Connecticut, Xerox Corporation requested bids for the construction of its new headquarters. Each of the bidders spent several thousand dollars to prepare a cost estimate. Did the price that Xerox paid for its corporate headquarters include any of these estimation costs?

¹See Engelbrecht-Wiggans (1980) for a survey of the literature. Vickery (1961), Wilson (1967, 1977), Baron (1972), Goldberg (1977), Reece (1978), Holt (1980), Copping, Smith and Titus (1980), and Riley and Samuelson (1981) examine various aspects of the competitive bidding problem.

Both of these examples present a conundrum. If competition forces firms to charge marginal cost, why would firms ever invest in resources which are not marginal and hence are unrecoverable?²

One solution to this gap in economic theory has been to include such things as bid preparation costs in the marginal cost, but that misses our point. For example, a construction company's bid preparation costs are sunk when the bid is tendered. These costs cannot be marginal. For firms in this industry to survive in the long-run, the textbook prediction that price equals marginal cost cannot be accurate if it is to be applied at all times in the production process. Clearly the conventional approach is useful in describing the ex ante equilibrium - before any resources are spent - but it cannot also be correct when the bids are tendered.

In this paper, we examine the effect of pre-bid costs on the competitive bidding process. Wilson's (1977) model of sealed-bid auctions provides a useful framework for analyzing this problem. In section 2, we show that, with a finite number of companies bidding for an asset, it is in the interest of every bidder to bid less than he thinks the asset is worth. The expected value of the winning bid is lower than the expected value of the asset -- there is some expected profit left over for the winner. This expected profit is what causes firms to invest in bid preparation. Therefore, firms can correctly treat estimation costs as sunk when they tender their bids and still, on average, recover these costs.

If the bidders expect to recover their estimation costs, the asset owner must expect to pay these costs; the owner's expected revenue is equal to the

²Note that our examples involve all-or-none decisions so that there are no infra-marginal rents which can be used to pay fixed or sunk costs.

expected value of the asset minus all of the pre-bid costs. Section 3 considers several strategies the owner might use to increase his expected revenue.

The fourth section extends our model to a number of consumer goods markets. For example, the process of collecting estimates for home repair can be viewed as a sealed-bid auction. However, there is an important difference between these auctions and the auctions examined in section 2. In the standard auctions in section 2, potential bidders determine how many bids will be submitted. In the consumer goods market this decision is made by the customer. This distinction allows us to make several predictions about those markets. For example, repair shops in high-income neighborhoods are more likely to advertise while shops in low-income neighborhoods are more likely to charge for estimates.

The fifth section summarizes the paper and discusses several implications of our model.

2. The Bidder's Problem

This section uses Wilson's (1977) model of competitive bidding to examine how firms recover pre-bid estimation costs. In this model, a number of identical firms compete in a sealed-bid auction, with the highest bidder receiving the asset offered for sale. Each firm is risk-neutral and attempts to maximize its expected payoff. Ignoring estimation costs, the winning bidder's profit is equal to the difference between the value of the asset, V , and the bid it submits, b_j , while the losers' profits are zero.

When the firms are determining their bids, we assume that they all know the number of competing bidders. However, none of them knows the actual value of the asset nor the bid of any other firm. We also assume that all of the firms start with the same prior distribution on the value of the asset, $G(V)$, and that each purchases a private sample of information about that value, I_j . These sample estimates of the value of the asset are drawn independently from the same conditional distribution, $F(I_j|V)$. Each firm calculates its bid based on the prior distribution of the value, the number of bidders, n , and its own sample of information.

The bidding process can be broken into two steps. First, each firm estimates the value of the asset as if it has received the most optimistic sample of information. Since the firms are identical, this means that each firm assumes that it will win the bid. Obviously, most of the firms will be making this assumption incorrectly. However, the winning firm -- which correctly assumes that it will win -- is the only bidder that affects its payoff by making this assumption.

Suppose firm i does win the auction. The act of winning provides valuable information; it implies that the firm has observed the highest private estimate of the asset's value -- its information sample is more positively biased than any other firm's sample. If the winning bidder does not correct for this "winner's curse" before submitting its bid, on average its estimate will be higher than the asset's true value. Therefore, by correctly predicting that it will win the auction, firm i can form a more accurate estimate of the asset's value and improve both its bid and its expected payoff.

Usually firm i will be wrong in assuming it has received the most optimistic sample of information. This error will cause the firm to form a downward biased estimate of the value of the asset. However, since the firm would not have won the bid anyway, this error has no effect on its payoff.

Before the bids are opened none of the firms knows whether it will win or lose. However, since the eventual winner improves his payoff by assuming he will win, while the eventual losers do not affect their payoffs, all of the firms improve their ex ante expected payoffs by assuming they will win. Therefore, the first step in each firm's bidding process is to form an estimate of the asset's value assuming that it has received the most optimistic sample of information.

The second step for firm i is to determine its bid based on its adjusted estimate of V . While it might appear that the bid should equal this estimate, in general this will not be the case. This strategy would result in the winning bidder paying the expected value of the asset -- which is equivalent to the competitive solution of price equaling marginal cost. Ignoring estimation costs, this strategy would also result in an expected profit of zero for all bidders.

Firm i can improve its expected profit by submitting a bid which is slightly below its adjusted estimate of the asset's value. To see why, assume that the other firms do bid their adjusted estimates and firm i reduces its bid. As Table 1 indicates, this can lead to three different results. First, firm i may not have observed the highest sample of information. In this case, reducing its bid will not affect the firm's expected profit since it would not have won the auction anyway. Second, firm i may have observed the highest sample and submit a bid which is below the next highest bid. In other words, reducing its bid below its adjusted estimate of the asset's value may cause firm i to lose the auction. Ignoring estimation costs, the firm's expected profits are zero in this case -- exactly what they would be if the firm bid its adjusted estimate. Finally, firm i may win the auction. This will happen if firm i has observed the highest sample and submits a reduced bid which is above the next highest bid. Since the firm is bidding below its adjusted estimate of the asset's value -- the firm's expectation of the value, conditional on winning -- its expected profit is positive. In both the first and second cases, firm i does not affect its expected payoff by bidding below its adjusted estimate. However, in the third case this strategy is more profitable than bidding the adjusted estimate. As long as there is some chance that the third case will occur -- and there is with a finite number of bidders -- firm i will increase its profits by bidding below its adjusted estimate of the asset's value.

This argument predicts that firm i will submit a bid that is below its adjusted estimate of the asset's value. However, it does not indicate how much firm i will reduce its bid, nor does it recognize that the other firms will also bid below their own adjusted estimates. In fact, since the firms are identical they must use the same bidding strategy. Wilson (1977) derives

Table 1
 Expected Profit Under Alternative Bidding Strategies
 When Other Firms Bid Their Adjusted Estimates of the Asset's Value^a

| Strategy | Private Estimate | Outcome | Expected Profit |
|--|------------------|---------|---|
| Bid adjusted estimate of asset's value $b_j = E(VII_j \text{ is highest sample})$ | Not highest | Lose | $E(II)=0$ |
| | Highest | Win | $E(II)=E(VII_j \text{ is highest sample}) - b_j$ $= 0$ |
| Bid below adjusted estimate of asset's value $b_j < E(VII_j \text{ is highest sample})$ | Not highest | Lose | $E(II)=0$ |
| | Highest | Lose | $E(II)=0$ |
| | | Win | $E(II)=E(VII_j \text{ is highest sample}) - b_j$ > 0 |

^aThe expected profit in this table ignores the estimation costs.

the optimal bidding strategy for this model. As we demonstrate in the appendix, Wilson's profit maximizing strategy has a very appealing interpretation; the optimal bid for each firm occurs at the point where the expected marginal revenue from lowering the bid one dollar equals the expected marginal cost. Firm i gains by lowering its bid because this reduces the price it must pay for the asset if it wins the auction. However, there is also a potential cost; lowering the bid reduces the firm's probability of winning. The firm lowers its bid until the expected marginal revenue from reducing the cost of the asset equals the expected marginal cost from reducing the probability of winning.

In summary, each firm obtains an initial estimate of the value of the asset. The firm then makes an adjustment to this estimate to correct for the possibility that its initial estimate was the highest -- the winner's curse. The firm now has an unbiased estimate of the value of the asset conditional on being the winning bidder. Given this unbiased estimate the firm calculates its most profitable bid. The firm will not bid the value of the asset -- price is not equal to marginal cost. Instead the firm uses a different marginal condition. Given the number of competitors, the firm reduces its bid below its estimate of the asset's value to the point where the expected cost of reducing the bid one more dollar equals the expected revenue.

The fact that the winning bidder does not bid its adjusted estimate of the asset's value presents a partial solution to the question of how firms recover their pre-bid costs. Ignoring these estimation costs, each firm has a positive expected profit when its bid is tendered. However, as the model has been developed so far, there is nothing which requires this expected profit to equal the pre-bid costs. Firms still might not expect to recover all of their estimation costs. Alternatively, a firm's expected profit might be higher than these costs, even in the face of intense competition.

The second half of the estimation cost puzzle can be solved by observing that the number of bidders is determined endogenously. If each bidder's expected profit falls as the number of bidders increases, new firms will enter until the expected profit from bidding equals the expected cost. In equilibrium, there will be no incentive for new firms to enter and yet the bidding firms will, on average, recover their sunk costs.

This equilibrium argument relies on the proposition that each bidder's expected profit falls as the number of bidders increases. There are two reasons why this condition should hold.³ First, as the number of bidders increases, the probability of any particular bidder winning the auction falls. Each bidder is less likely to receive a positive payoff. Second, the winner's payoff is likely to fall as the number of bidders increases.

The expected payoff to the winning bidder is positive because each firm bids below its adjusted estimate of the asset's value. As the number of bidders increases, each firm will narrow the gap between its bid and its adjusted estimate, reducing its payoff if it wins. To see why firms will behave this way, assume firm i has received the most optimistic sample of information, I_i . As the number of bidders increases, the expected difference between I_i and the next highest information sample falls. Therefore, there is a higher probability that firm i will lose the auction as it reduces its bid below its adjusted estimate. This increases the cost of lowering its bid without increasing the benefit. With more bidders, firm i will not reduce its bid below the perceived asset value as much as it will with fewer bidders. In fact, neither firm i nor any other firm knows whether it has observed the highest sample. However, since each firm forms its bid under this assumption,

³It is conceivable that, under perverse distributional assumptions, the expected profit will be an increasing function of the number of bidders over some range. However, as the discussion below makes clear, this possibility is economically irrelevant. Firms will enter until the expected profit is in the decreasing range and the equilibrium condition holds.

this argument applies to all of them; increasing the number of bidders leads each firm to reduce the gap between its bid and its adjusted estimate of the asset's value.

To summarize, each bidder's expected profit falls as the number of bidders increases for two reasons. First, the expected profit for the winning bidder falls. Second, the probability that any particular firm will win and obtain this expected profit also falls.

Figure 1 illustrates how a potential entrant decides whether to prepare a bid or not. Before beginning its estimation process, firm i has a prior estimate of the asset's value $E(V)$. It also forms an expectation of the winning bid, $E[B(n)]$, which increases with the number of bidders. If there are currently $n-1$ firms preparing bids and firm i decides to enter, the expected profit for the winning bidder will be

$$E(\pi_n | \text{Win}) = E(V) - E[B(n)] \quad . \quad (2.1)$$

Since each bidder is equally likely to win, the potential entrant's expected profit from bidding, ignoring estimation costs, is

$$E(\pi_n) = \frac{1}{n} E(\pi_n | \text{Win}) \quad (2.2)$$

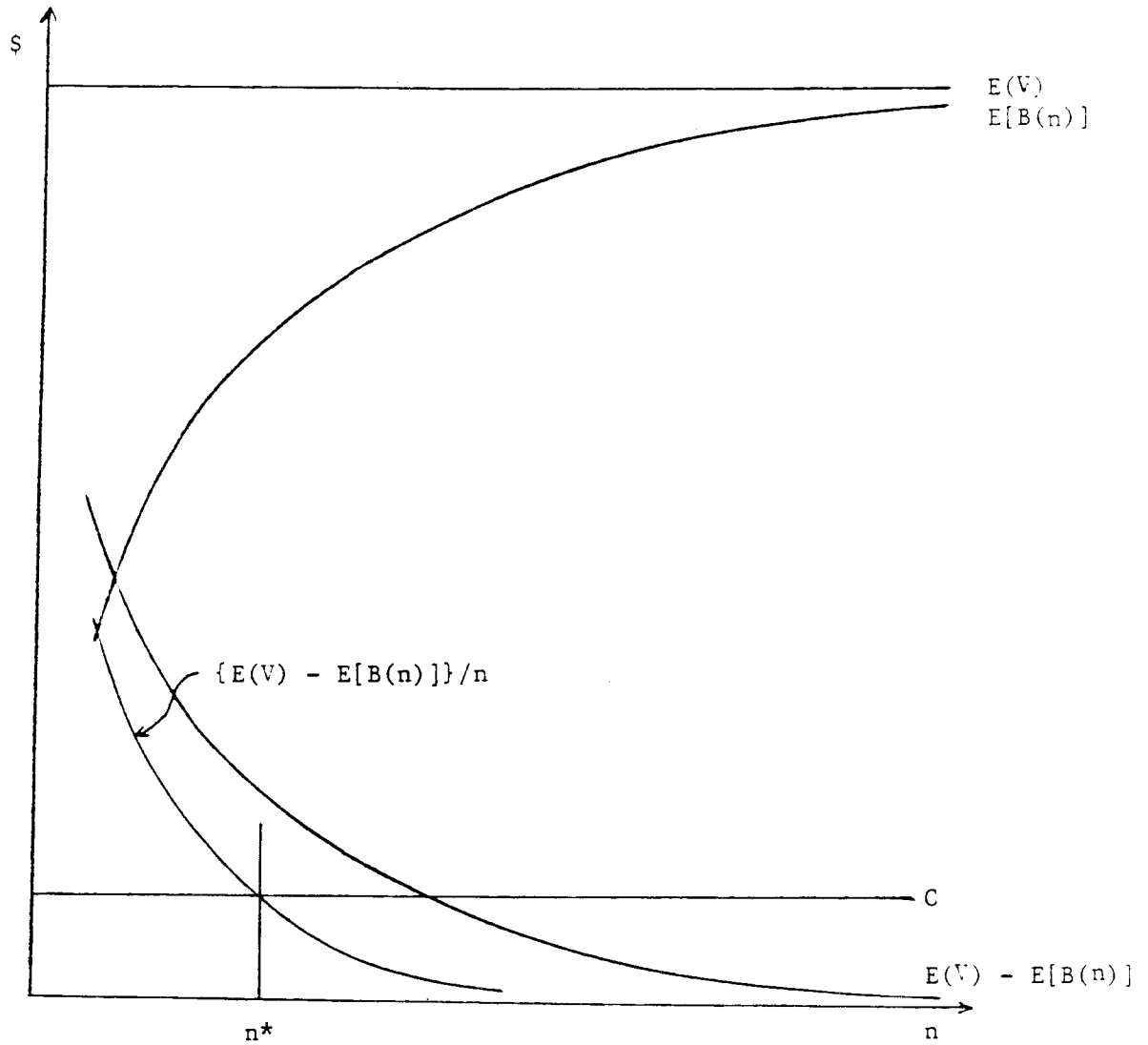
$$= \frac{1}{n} \{E(V) - E[B(n)]\} \quad . \quad (2.3)$$

The equilibrium number of bidders, n^* , occurs where the expected profit from bidding equals the bid preparation costs,

$$E(\pi_{n^*}) = C \quad . \quad (2.4)$$

Figure 1

Determining the Equilibrium Number of Bidders



In this figure, $E(V)$ is the expected value of the asset, $E[B(n)]$ is the expected value of the winning bid when there are n bidders, and $E(V) - E[B(n)]$ is the expected profit for the winning bidder. Firms enter the auction until the expected profit from bidding, $\{E(V) - E[B(n)]\}/n$, equals the cost of bidding, C .

If fewer than n^* firms have committed resources to bidding, other firms will enter the auction because their expected profits, net of their pre-bid costs, are positive. However, once n^* firms are competing, no other firm will enter because its expected profits will not cover its estimation costs. In fact, if a new firm did enter the auction it would also drive everyone else's expected profits below their (now sunk) estimation costs.

3. The Asset Owner's Problem

In the previous section we assumed that the asset owner would choose to sell his asset using a sealed-bid auction. He actually has a wide variety of sales mechanisms to choose from. For example, he can use the simple sealed-bid auction of section 2 or he can complicate the auction with reservation prices and entry fees. Alternatively, he can use an ascending bid "English" auction, a descending bid "Dutch" auction, or a process of negotiation with a single buyer. He also has the option to release any information that he has or to lie about information that he does not have. In this section, we examine the effect of these alternative strategies on the owner's expected revenue when bidders incur estimation costs.

We will continue to assume that there are an infinite number of potential bidders with the same prior distribution about the value of the asset. Each of these firms acts to maximize its expected profit. The assumptions about the asset owner are very similar. He begins with the same prior distribution as the potential bidders and he attempts to maximize his expected revenue.

3.1 Entry Fees

Pre-bid costs have an important effect on the asset owner's expected revenue if he chooses to use the sealed-bid auction described in section 2. In fact, equations (2.3) and (2.4) imply that the owner's expected revenue is equal to the expected value of the asset minus all of the bid preparation costs,

$$\begin{aligned} E(R) &= E[B(n^*)] \\ &= E(V) - Cn^* \end{aligned} \tag{3.1}$$

In effect, the estimation costs are transferred from the bidders to the asset owner.

Since the asset owner must pay all of the estimation costs, he has a strong incentive to reduce them. One simple way to do this is to arbitrarily restrict the number of bidders. However, as Figure 2 illustrates, this will not increase the owner's expected revenue; reducing the number of bidders from n^* to n' just reduces the expected value of the winning bid from $E(B^*)$ to $E(B')$. In fact, the firms that are allowed to bid are the benefactors of this strategy. They capture both the reduction in the expected value of the winning bid and the reduction in the estimation costs. When the number of bidders is restricted, each bidder's expected profit is positive,

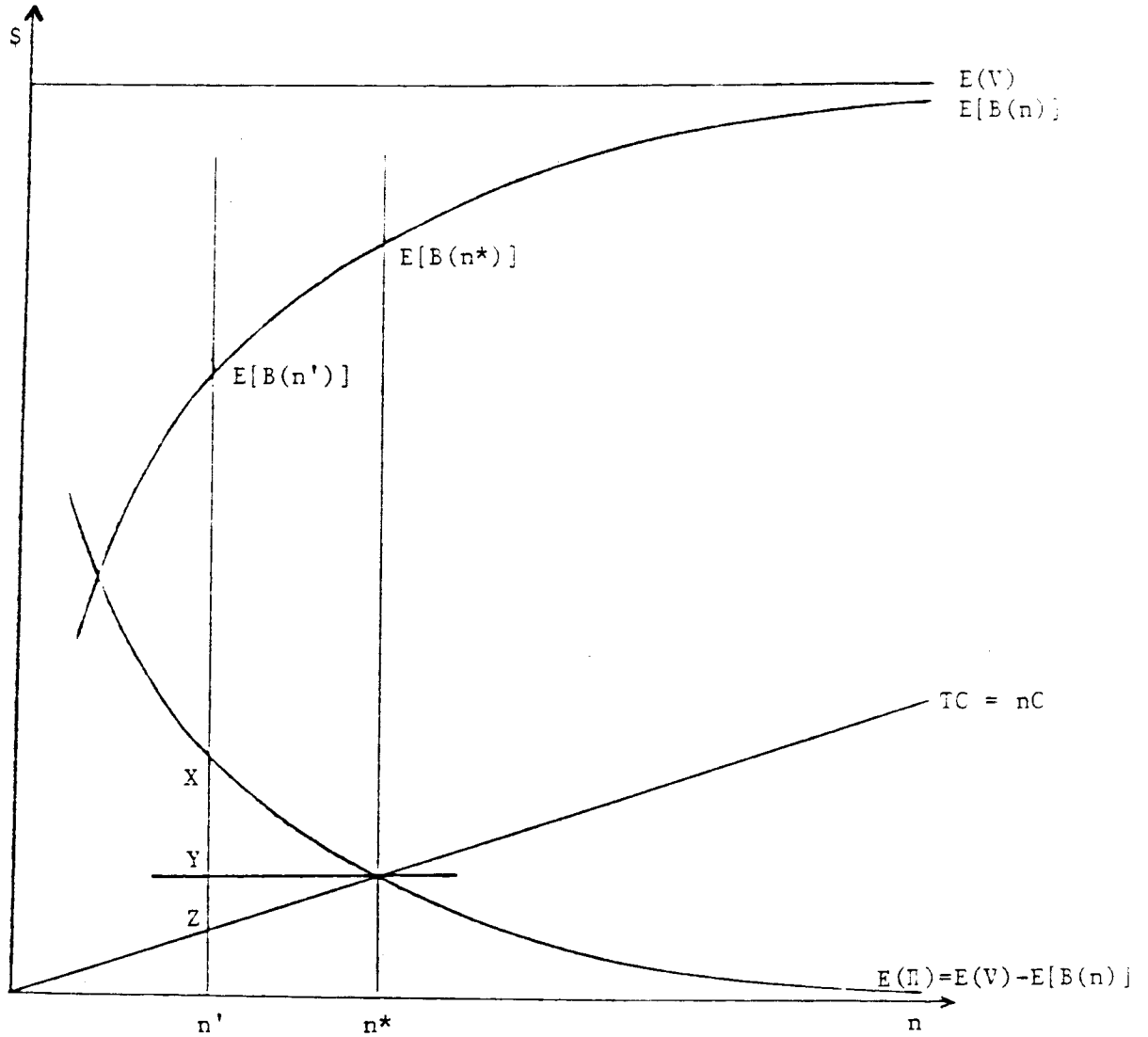
$$\begin{aligned} E(\pi_{n'}) &= \{E(V) - E[B(n')] - n'C\}/n' \\ &= \{E[B(n^*)] - E[B(n')] + (n^*-n')C\}/n' \\ &> 0 \end{aligned} \tag{3.2}$$

This suggests a more profitable way for the owner to reduce the estimation costs. Potential bidders would be willing to pay for the right to enter the auction if the asset owner limits the number of bidders to less than n^* .

Suppose the owner charges an entry fee that is equal to the per-firm profit in equation (3.2),

$$F = \{E(V) - E[B(n')] - n'C\}/n', \tag{3.3}$$

Figure 1
 The Effect of Arbitrarily Restricting
 the Number of Bidders



If the asset owner arbitrarily restricts the number of bidders to n' , his expected revenue falls from $E[B(n^*)]$ to $E[B(n')]$. The bidding firms capture both the reduction in the expected value of the winning bid, \overline{XY} , and the reduction in the total estimation costs, \overline{YZ} .

instead of restricting entry. If this fee is paid when a firm purchases its sample of information, it will not affect the bidding strategy of any firm that does purchase information. Therefore, the function relating the expected value of the winning bid and the number of bidders, $E[B(n)]$, is unaffected.⁴ However, the entry fee will change the number of bidders. Firms will enter until the expected profit from bidding equals the sum of the estimation costs and the entry fee,

$$\begin{aligned} \{E(V) - E[B(n)]\}/n &= C + F \\ &= C + \{E(V) - E[B(n')] - n'C\}/n' \\ &= \{E(V) - E[B(n')]\}/n' \quad . \end{aligned} \tag{3.4}$$

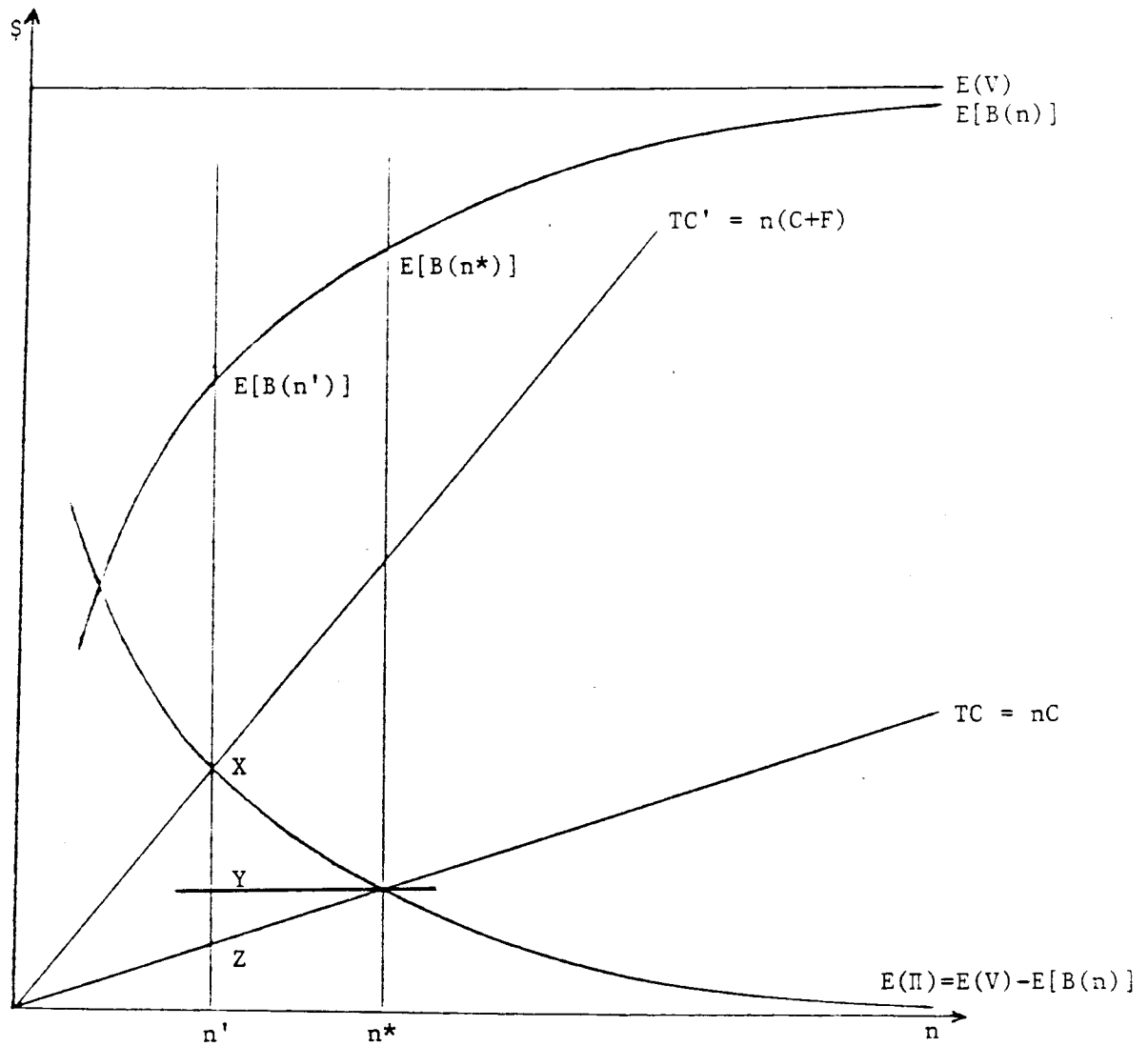
As Figure 3 illustrates, this particular submission fee reduces the number of bidders from n^* to n' .

The submission fee also reduces the expected value of the winning bid. However, now the owner's revenue includes both the winning bid and the submissions fees,

⁴The problem becomes more complicated if firms can choose whether to pay the entry fee after they have purchased their information. In this case the relation between the expected value of the winning bid and the number of firms purchasing information is affected by the entry fee. For example, suppose the most optimistic firm's adjusted estimate is below the entry fee. If the fee is paid after firms purchase their information, no one will bid. Several papers, including Riley and Samuelson (1981) and Milgrom and Weber (1982), examine the effect of entry fees on the owner's expected revenue. However, in these papers the number of potential bidders (who are simply endowed with information) is specified exogenously.

Figure 3

The Effect of Entry Fees



If the owner charges an entry fee of F he reduces the number of bidders from n^* to n' . The expected value of the winning bid falls by \overline{XY} , from $E[B(n^*)]$ to $E[B(n')]$. However, the owner also receives $n'F$, or \overline{XZ} , in fees. Therefore, his total expected revenue increases by \overline{YZ} , the reduction in the estimation costs.

$$\begin{aligned} E(R) &= E[B(n')] + n'F \\ &= E[B(n')] + E(V) - E[B(n')] - n'C \\ &= E(V) - n'C \end{aligned} \quad (3.5)$$

As in the case of no submission fees and unrestricted entry, the owner expects to recover the total value of the asset minus all of the estimation costs. However, in this case the fee reduces both the number of bidders and the total estimation costs, so the asset owner's expected revenue is higher.

This result suggests that the asset owner should raise the fee until only two firms compete in the auction. Unfortunately, this implication is an artifact of our simplifying assumptions. We have ignored several potentially important factors. For example, we have assumed that the information purchased by each bidder is completely non-productive -- that the actual value of the asset is not affected by this information.⁵ In fact, the bidders' information usually increases the expected value of the asset.

The increase in the asset's value can occur for two reasons. First, the bidders' search may improve the allocation of the asset so that the highest value user receives it. For example, if some oil companies specialize in deep wells while others specialize in shallow wells, pre-bid exploration can improve the allocation by identifying which companies should bid aggressively for a particular oil lease.⁶ Pre-bid information can also increase the expected

⁵If information is entirely non-productive, the asset owner would actually like to eliminate all investment in information. See Barzel (1977) for a general discussion of this issue.

⁶We would like to thank Robert Hansen for suggesting this example. The bidding strategy described in the appendix is not the optimal strategy if the true value of the asset may be different for different bidders. Milgrom and Webber (1982) develops the optimal strategy for this case.

value of the asset by improving the production plans of the competing firms. Both of these factors imply that the expected value of the asset increases with the number of bidders. Each new bidder may discover that he is particularly well suited for this asset or he may discover a particularly efficient plan for using the asset.⁷

When the expected value of the asset is independent of the number of bidders, the asset owner can control the number of bidders by charging an entry fee. Moreover, his total expected revenue always equals the expected asset value minus the total estimation costs. These results carry over directly to the case of a varying asset value. The owner's expected revenue equals

$$E[R(n)] = E[V(n)] - nC. \quad (3.6)$$

The owner would like to select the entry fee -- or, equivalently, the number of bidders -- that maximizes his expected revenue. The first-order condition for this maximization is

$$\frac{\partial E[R(n)]}{\partial n} = \frac{\partial E[V(n)]}{\partial n} - C = 0. \quad (3.7)$$

The asset owner will increase the entry fee and reduce the number of bidders until the marginal reduction in estimation costs equals the marginal reduction in the expected value of the asset.

⁷If these two types of information were produced separately, they would have different effects on the owner's expected revenue. Over some range of investment, the benefit of improved allocation may be larger than the cost of the information. On the other hand, pre-bid production of information about the efficient way to use the asset always reduces the owner's expected revenue. The winner can produce the "right" amount of information -- without duplication -- after the auction. However, the production of these two types of information usually cannot be divorced.

The model in section 2 also ignores the possibility of collusion. By reducing the number of bidders, the owner increases the probability that the remaining bidders will collude against him. There are several ways to model this potential problem. The simplest way is to assume that any collusion occurs after all of the bidders have entered the auction and purchased their information. At that time a weighted coin is tossed. If it comes up heads, the collusion is successful and the bidding firms receive the asset without paying anything more. If it comes up tails, the collusion is unsuccessful and the bidding firms compete against each other using the strategy described in section 2. Defining $p(n)$ as the probability of a successful collusion when there are n bidders, the expected value of the winning bid is

$$E[\bar{B}(n)] = [1 - p(n)] E[B(n)]. \quad (3.8)$$

In this model collusion reduces the expected value of the winning bid. However, it does not necessarily affect the owner's expected revenue. Since firms will compete for the right to be among the potential colluders, the owner can offset the expected reduction in bid revenue by increasing the entry fee.

The possibility of collusion does affect the owner's expected revenue if resources are spent in attempting to collude and in trying to prevent collusion. Define $H(n)$ as the total resources spent when there are n bidders. Then the expected revenue is equal to

$$E[R(n)] = E[V(n)] - nC - H(n). \quad (3.9)$$

The revenue maximizing condition becomes

$$\frac{\partial E[R(n)]}{\partial n} = \frac{\partial E[V(n)]}{\partial n} - c - \frac{\partial H(n)}{\partial n} = 0$$

or equivalently,

$$c = \frac{\partial E[V(n)]}{\partial n} - \frac{\partial H(n)}{\partial n} . \quad (3.10)$$

The owner increases the fee and reduces the number of bidders until the marginal reduction in estimation costs equals the marginal reduction in the expected value of the asset minus the marginal increase in the resources devoted to collusion.

3.2 The Production of Information by the Asset Owner

On average, the asset owner pays for the information that is produced in a sealed-bid auction. Therefore, he would like that information to be produced efficiently. One way to accomplish this is by generating some information himself. This eliminates the duplication of effort that occurs when several bidders produce the same information. For example, the government might perform seismographic tests on an offshore oil tract and release this information to potential bidders.

This solution is not as simple as it may seem because of the conflict of interest between the owner and the bidders. The owner has an incentive to provide optimistic information about the value of the asset. In fact, unless the owner can be policed he will probably be ignored.

Fortunately, there are several ways for the owner to establish his credibility. For example, he might post a bond that will be given to the winning bidder if his information is false. If the owner plans to hold other auctions,

he may not even have to post a bond. As Klein and Leffler (1981) demonstrate, the adverse effects on his future revenues can act as an enforcement mechanism. Finally, the owner might hire an independent firm, such as a bond rating agency, to provide information.

These factors allow us to make several predictions. First, the owner or his agent will produce objective information that can be communicated easily. For example, we expect an art dealer to estimate and reveal the age of an ancient Chinese vase. However, we do not expect him to spend many resources trying to inform potential bidders about the aesthetic qualities of the vase. We also predict that owners who return to the market frequently will provide information themselves while other owners will hire outside agencies.

3.3 Negotiation

The asset owner might use a number of other strategies to reduce the bidders' investment in information. For example, he might offer to sell the asset for slightly less than $E(V)$, the mean of the asset's value. This would be successful if the owner could prevent the potential bidders from purchasing any information. Since the potential bidders have the same prior distribution as the owner, they would be willing to buy the asset for $E(V)$.

Unfortunately, the potential bidders still have an incentive to acquire information about the asset's value. Suppose a bidder invests C for a sample of information. He is now better informed than the seller. If his updated estimate of the asset's value is above $E(V)$, the informed bidder will be happy to buy the asset at the owner's price. However, if his updated estimate is

less than $E(V)$, he will not offer to buy the asset. This asymmetry drives the owner's expected revenue below $E(V)$.⁸

The asset owner could solve this problem by initially offering the asset for a very high price and then lowering the price until one firm agrees to purchase the asset. This sales technique is called a Dutch auction. Although it solves the adverse selection problem, this auction does not reduce the resources consumed in bid preparation. In fact, this auction is analytically equivalent to the sealed-bid auction described in section 2.

There is an alternative way for the owner to solve the adverse selection problem; he can negotiate with one of the potential bidders. By forcing the buyer to share his information, the owner can obtain a higher payment when the updated estimate is above $E(V)$. In addition he will be able to sell the asset when the updated estimate is below $E(V)$.

Unfortunately, there are costs associated with this negotiation strategy. First, the owner is giving some monopsony power to the firm he chooses to negotiate with. Since the buyer has some information that is not available to the seller, the seller cannot capture the full updated estimate of the asset's value. A second cost arises if the actual value of the asset varies with the identity of the buyer. The buyer chosen by the owner might not place the highest value on the asset. Finally, the actual process of negotiation can be expensive. We expect firms to use negotiated sales instead of auctions if these costs are small when compared with the costs of bid preparation. For example, if there is not much dispersion in the true value of the asset across

⁸Note that uninformed firms will not compete against the informed buyer. If the asset is allocated randomly among the firms who offer to buy it, uninformed firms will find that they have a disproportionately high probability of receiving the asset when the actual value is below $E(V)$. Also note that the informed firm's decision rule is complicated by the winner's curse if there are other informed firms.

the potential buyers (or if the owner can determine the highest valued user ex ante) the asset owner is more likely to use a negotiated sale. Low negotiation costs will also lead to negotiated sales. For example, suppose the owner has an on-going relationship with a potential buyer. This will tend to reduce the negotiation costs and increase the probability that the owner will choose a negotiated sale.⁹

⁹Contracts between friends and relatives at lower-than-normal prices are consistent with this theory. Since bargaining costs are lower, negotiations are used and the reduction in the bid preparation costs is split between both parties.

4. Bidding Applications

The bidding model of section 2 can be extended to a number of consumer goods markets. For example, the usual process for purchasing home, television, and camera repairs is very similar to a sealed bid auction; each repair shop forms an estimate of its costs and submits a bid without knowing its competitors' bids. However, there is one important difference. In the auctions examined in section 2, the number of bidders is determined by the bidders; they enter until the next bidder's expected profit would be negative. In the consumer goods markets, the individual purchasing the service usually determines the number of bidders. This distinction leads to substantial differences in the day-to-day operations of these markets.

Consider the problem from the point of view of the prospective buyer in a consumer goods market. He will collect bids until the marginal cost of search equals the expected marginal benefit. Assume that each buyer forms an expectation of the costs and benefits of search and calculates the optimal number of bids to collect before he begins searching. Further, assume that each bidder makes an accurate forecast of this number and uses it as an input in the bidding model of section 2.

The buyer's expected marginal benefit of search is equal to the expected reduction in the price he has to pay because there are more bidders. Two factors contribute to this reduction. First, there may be differences in the true cost of the product or service across the bidders. For example, in the process of estimating their bids, different camera repairmen may discover different ways to fix a broken camera. Since each new bidder may discover a cheaper process, the expected cost falls with the number of bidders. The second benefit from search arises because of the finite-bidders adjustment

discussed in section 2. If the buyer chooses to canvas n repair shops instead of $n-1$ shops, the bids he receives will reflect the increased competition. Each bidder will reduce the amount he raises his bid above his adjusted estimate of the repair cost, so the winner's expected profit falls. Both of these factors imply that the price the buyer expects to pay for the service falls as he increases the number of bidders.¹⁰

Figure 4 illustrates the buyer's problem. In this figure, nC is the total estimation costs for all of the bidders and $E(V)$ is the winner's expected cost of performing the service. This expected cost falls as the number of competitors increases because each new firm may discover a more efficient way to produce the service. The winning bidder's expected profit, ignoring estimation costs, is equal to the difference between the expected value of the winning bid and the winner's expected costs, $E(\Pi) = E[B(n)] - E(V)$.

In a normal sealed-bid auction, equilibrium occurs when there are n^* bidders and the winner's expected profit equals the industry's total estimation costs. However, the searcher will choose n^* only by accident. Instead, the buyer goes to the point where the cost of acquiring one more bid, S , equals the reduction in the expected value of the winning bid. Figure 4 depicts three of the many possibilities. If the buyer's marginal cost of search is equal to $(-)S_1$, he will choose n_1 bidders. If the cost of search is S_2 he will choose n^* , and if the marginal cost is S_3 he will solicit n_3 bids.

In the first case, a profitable opportunity exists for the lucky n_1 bidders and other retailers would like to induce the buyer to collect bids from them. Advertising, increased product variety, and a better location are all strategies a retailer might use to accomplish this. These strategies have two

¹⁰The benefit of search is slightly different if the retailers are not able to observe the number of bids being collected. In this case, each bid is drawn from a distribution that does not change when a particular individual solicits more bids. Although the benefit from search is now equal to the change in the expected value of the order statistic, the general results are the same.

effects: they reduce the buyer's search costs so that more bids are collected and they increase the sellers' pre-bid costs. When there is competition among the sellers, this process will continue until there are no profits in the industry.

By contrast, in those situations where the search costs are relatively low the buyer will search "too much." This is the case at point n_3 in Figure 4. The industry cannot survive in the long-run; the expected profits from bidding are below the costs. One solution to this problem is for the retailers to charge for estimates. This will increase the buyer's search costs and reduce the sellers' estimation costs. This solution leads to a zero-profit equilibrium at point n_4 in Figure 4.¹¹

Three factors determine whether the buyer's optimal number of bids, n' , is originally above or below the industry equilibrium: the relative sizes of the cost of bid preparation, the cost of search, and the benefit of search. This model predicts that in industries where buyers face low search costs, where the payoffs to search are high, and where bid preparation costs are high the sellers are likely to charge for their estimates. Consider camera repairs. Because the product is complicated, each serviceman must spend a great deal of time examining the camera before he will provide a binding estimate. At the same time, the benefits from search are high because there is a large probability that a new bidder will discover an unusually efficient repair technique. By contrast, some services, such as carpet installation, roof repair, and

¹¹A second process has also evolved to solve the "too many bids" problem. Some repair shops provide a precursory, non-binding bid for free. When the customer accepts a bid, the shop updates its estimate as it undertakes the repair. If this updated bid is above the original estimate, the customer can decide that the repair should not be completed. This process reduces the number of binding bids collected for two reasons. First, the direct search costs are increased. Second, the benefits of search are reduced because binding estimates must be collected sequentially; since a customer cannot return to a shop after balking at an updated estimate, he must sample without recall.

driveway sealing, are relatively homogeneous and easy to estimate. Moreover, there is usually not a large chance that the buyer can uncover a particularly low-cost repair method. Both of these factors imply that camera repair shops are more likely to charge for binding estimates, while home repair shops are less likely to charge. Further, the home repair firms will probably do more advertising.

This model also predicts that stores with different clienteles will use different marketing strategies. For example, repair shops in high income neighborhoods are likely to face customers with higher search costs than shops in poor neighborhoods.¹² Therefore, the high-income shops are more likely to advertise than low-income shops. On the other hand, repair shops in poor neighborhoods are more likely to charge for estimates.

In summary, if a firm charges its customers for bids, it is because the customers are canvassing too many bidders. On the other hand, non-price advertising is often used to increase the number of bids solicited. Therefore, this model predicts that firms which charge for bids will not do much advertising.¹³

Firms can also affect a buyer's search costs in several other ways. For example, when prospective customers are collecting too few bids, stores can increase their hours of operation, making it cheaper to collect information.

¹²In a household production sense the effect of income on search costs is ambiguous. In general, rich people will have a high opportunity cost of time, but they may be efficient searchers. If the marginal productivity of time spent searching increases with income, the effect of income on search costs must be determined empirically. However, if the marginal productivity of search increases at a decreasing rate over the relevant income range, the opportunity cost of time will eventually dominate. This implies that rich people face higher search costs than poor people.

¹³Obviously, there are other reasons why firms might advertise or charge for bids. For example, advertising might be used to develop brand name capital as a bonding device (see Klein and Leffler, 1981). Estimation fees might be used in a two-part pricing scheme (see Oi, 1971, and Murphy, 1977). See Butters (1977) for an additional discussion of advertising in the context of bidding models.

Camera and auto body repair shops are more likely to be open at night and on weekends in rich, high-search-cost neighborhoods. A shop's location and general attractiveness also affects potential customers's search costs. We expect that stores catering to high-search-cost customers will be very visible and accessible. They will also be cleaner, less crowded, and more fully staffed than their low-search-cost counterparts.¹⁴

¹⁴For a discussion of product quality and the value of time see De Vany (1976) and Becker (1965).

5. Summary

The textbook solution to the recovery of sunk costs depends on rising marginal costs. We have developed a bidding model of the competitive process that does not rely on this assumption. The central feature of this model, which is based on Wilson's (1977) model of sealed-bid auctions, is the distinction between competitive equilibria before and after resources are committed. Ex ante, there are an infinite numbers of potential competitors. This guarantees that a zero-profit equilibrium will prevail. However, after the initial investments are made only a finite number of competitors remain. It is this reduction that allows the remaining firms to recover their non-sunk estimation costs. With a finite number of competitors, each firm recognizes that there will be a gap between its adjusted estimate of the asset's value and the adjusted estimate of its closest rival. Each firm exploits this gap by bidding less than its adjusted estimate. In other words, the winning bidder is expected to earn a profit. This profit induces firms to invest in bid preparation. In fact, firms enter the auction until the winner's expected profit equals the industry's estimation costs.

In this model, sealed-bid auctions are like lotteries and fair games. Since the winning firm captures the industry's sunk bid preparation costs, the value of each of the $(n-1)$ losing firms falls by its pre-bid costs and the value of the winning firm rises by $(n-1)$ times its pre-bid costs. The fact that the stock price of a defense contractor, an offshore oil lessee, or a building contractor rises on announcement that they have won a sealed bid auction does not, by itself, constitute evidence that the bidding process was not competitive.

If the winning bidder captures the industry's estimation costs, the asset owner must expect to pay these costs. This simple result has some important implications. For example, consider the auctions that the United States government uses to award offshore oil leases. In a recent paper analyzing the distribution of rents in these auctions, Reece (1978) reports several simulations relating the number of bidders and the size of the winning bid. His results are consistent with our predictions in section 2; holding all other variables fixed, the expected value of the winning bid increases as the number of bidders increases. Further, he finds that "the expected value of the winning bid may be substantially less than the true value of the lease..." when the bidding firms make reasonable assumptions about the number of competitors they face (Reece (1978), p. 383).

Both our analysis and Reece's simulations are based on Wilson's (1977) model of competitive bidding. However, there is an important difference between the two applications of this model; Reece does not include bid preparation costs in his theory. This difference leads to considerably different interpretations of his results. Reece views the predicted divergence between the lease value and the winning bid as evidence of a lack of competition and a sign that the oil industry may be capturing a "remarkably large fraction of the economic rent" associated with the leases. Our interpretation of these results is significantly different. When pre-bid costs are included in the model, this predicted divergence provides no evidence that the oil industry is capturing rents. It simply reflects the fact that the winning bidder must, on average, recover the industry's estimation costs. In other words, even in an auction with identical firms and unrestricted entry, the government's expected revenue will not equal the expected lease value unless there are no bid preparation costs.

Many economists have examined the issue of optimal auction design. For example, Milgrom and Weber (1982) conclude that, when bidders are risk-neutral and their value estimates are statistically dependent, "[t]he English auction generates the highest prices followed by the second price auction and, finally, the Dutch and first-price auctions." These economists generally assume that there is an exogenously specified set of bidders and that these bidders have been endowed with information. They ignore both potential entry and bid preparation costs. As we demonstrate in this paper, these factors play an important role in determining the owners' expected revenue.

We present a very preliminary discussion of the effect of different sales mechanisms on the expected revenue when entry and estimation costs are included in the model. However, we assume that all bidding firms invest the same amount in bid preparation and that this amount does not vary with the number of bidders. Moreover, we ignore the sequential nature of information acquisition. All of these factors may have an important effect on the sales mechanisms owners actually select.

Appendix

In this appendix we demonstrate that, under the assumptions outlined in section 2, each firm's optimal bid occurs at the point where the expected marginal revenue from lowering the bid one dollar equals the expected marginal cost. Wilson (1977) shows that, for this bidding model, the optimal bid for each competitor must satisfy the condition¹

$$\int_0^{\infty} [V-b(I_i, n)] Q_n'(I_i | V) \sigma_n'[b(I_i, n)] f(I_i | V) dG(V) = \int_0^{\infty} Q_n(I_i | V) f(I_i | V) dG(V), \quad (1)$$

where V = the (unknown) value of the asset,

I_i = the information sample observed by firm i ,

n = the total number of bidding firms,

$b(I_i, n)$ = the optimal bid based on the sample of information I_i when there are n bidders,

$G(V)$ = the prior distribution for the value of the asset,

$F(I_i | V)$ = the cumulative density function for I_i when the asset's value is V ,

$f(I_i | V)$ = the probability density function of $F(I_i | V)$,

$Q_n(I_i | V) = F(I_i | V)^{n-1}$ = the probability that no other firm receives a higher sample of information than firm i , conditional on the value of the asset being V ,

$Q_n'(I_i | V) = (n-1)F(I_i | V)^{n-2}f(I_i | V)$

$\sigma_n(b)$ = the level of information a firm must receive to bid b ,

$\sigma_n[b(I_i, n)] = I_i$,

$\sigma_n'(b)$ = the derivative of $\sigma_n(b)$ with respect to b .

¹In fact, Wilson deals with a more general model in which the winner's payoff is not necessarily equal to V minus the winning bid. See Wilson for the regularity conditions required to prove equation (1).

Consider the right hand side of equation (1). If the value of the asset is V , $Q_n(I_i|V)$ is the probability that no other firm receives a higher sample than I_i . Since the firms are identical except for their sample of information, this is also the probability that firm i wins the auction. This probability is weighted by the firm's marginal probability that the asset's value is V , $f(I_i|V)dG(V)$. Integrating this weighted probability over all possible values of V gives the firm's perceived probability of winning the bid. This is also the expected marginal revenue from lowering the bid one dollar since the gain from this reduction is only realized if firm i wins the bid.

The left hand side of equation (1) is the expected marginal cost of lowering the bid by one dollar. If firm i wins, its payoff is $V-b(I_i,n)$. The marginal probability that the most favorable sample observed by any other firm is I_i is given by $Q'_n(I_i|V)$. The function, $\sigma_n[b(I_i,n)]$, gives the minimum sample another firm would have to observe to bid higher than firm i , so $\sigma'_n[b(I_i,n)]$ is the amount firm i lowers this minimum when it reduces its bid by one dollar. Therefore, if the asset's value is V , $Q'_n(I_i|V)\sigma'_n[b(I_i,n)]$ is the amount firm i reduces its probability of winning by decreasing its bid one dollar and $[V-b(I_i,n)]Q'_n(I_i|V)\sigma'_n[b(I_i,n)]$ is the amount it lowers its expected payoff. Weighting this amount by the marginal probability that the asset's value is V , $f(I_i|V)dG(V)$, and integrating over all possible values of V gives the reduction in the firm's expected payoff when its bid is lowered by one dollar. In other words, equation (1) says that firm i should decrease its bid until the marginal cost of lowering it one more dollar equals the marginal revenue.

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