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ABSTRACT

Estimating the probability that a proposed bid will win is obviously a central problem in competitive bidding theory. Unfortunately, a method for doing this, which originated with Friedman and which continues to be expounded in the literature, is logically incorrect. This paper points out the deficiency in that formulation. (Author/MLF)

ON THE PROBABILITY OF WINNING IN COMPETITIVE BIDDING THEORY

by

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Estimating the probability that a proposed bid would win is obviously a central problem in competitive bidding theory. Unfortunately, a method for doing this which originated with Friedman[1] and which continues to be expounded in the literature[2] is logically incorrect.

Suppose n firms will submit s aled bids for a contract to provide a specified collection of goods and services. The lowest bidder will be awarded the contract. Let P_1 be the bid of firm 1, C_1' be firm 1's estimated cost of supplying the required goods and services, and P_2 through P_n the bids (random variables so far as firm 1 is concerned) of its competitors. Then, if $f(P_2, P_3, \ldots, P_n)$ is the joint density function of $P_2, P_3, \ldots, P_n$, the probability that a bid of amount P_1 will win is

$$\rho(P_1) = \int_{P_1}^{\infty} \int_{P_1}^{\infty} \cdots \int_{P_1}^{\infty} f(P_2, P_3, \ldots P_n) dP_2, dP_3, \ldots dP_n. \quad (1)$$

This is, of course, the probability that each competitor's bid will be higher than P_1.

Unfortunately, equation (1) is likely to be of little practical use in determining $\rho(P_1)$. Almost never will enough information be available to enable direct estimation of the joint density function with any reasonable precision unless some further simplifying assumptions can be made.

One helpful simplification would be the ability to factor the joint density function into the product of the density functions of each competing bidder. This cannot be done with the joint density function $f(P_2, P_3, \ldots, P_n)$. Since the bids are all made on the same bundle of goods and services, it is not possible to consider $P_2, P_3, \ldots, P_n$ as independent random variables; the bids of each firm must be somehow related to its estimated cost of producing the required commodities and surely the estimated production costs are not independent random variables.

Friedman [1] proposed the following method of attack:[1]

> One way of determining the probability of winning with a given bid lies in studying previous bidding data. Presumably the results of previous bidding on contracts are always announced, and from these announced bids, the "bidding patterns" of potential competitors may be studied. Suppose we are studying competitor 2. On every previous contract on which 2 bid and on which our company made a cost estimate, we take the ratio of 2's bid to our cost estimate. If there are enough previous contracts on which 2 has bid, a pattern of 2's bidding behavior relative to our cost estimates will emerge as a distinct distribution. These patterns can be made for all potential competitors ....
>
> Now if we know exactly which competitors are going to submit bids, the probability of winning for a given bid is relatively easy to compute. Assuming that each competitor is likely to bid as he has done in the past, which is the best assumption in the absence of additional information, the pro-

[1] I have changed Friedman's notation to conform with that in the rest of this note.

probability of being lower than competitor 2 by bidding P_1 is the area to the right of the ratio P_1/C_1' on 2's bidding distribution curve. Similarly, the probability of being lower than 3 is the area to the right of the ratio P_1/C_1' of 3's distribution curve. The probability of being the lowest bidder with a bid of P_1, when the competitors are known, is simply the product of the probabilities of defeating each of the known competitors.

In other words, Friedman believed that the conditional density function $f(P_2, P_3, \ldots, P_n \mid C_1')$ could be factored into $f_2(P_2/C_1') \cdot f_3(P_3/C_1') \ldots f_n(P_n/C_1')$ and that $\rho(P_1 \mid C_1') = \int_{P_1}^{\infty} f_2(P_2/C_1')\, dP_2 \int_{P_1}^{\infty} f_3(P_3/C_1')\, dP_3 \ldots \int_{P_1}^{\infty} f_n(P_n/C_1')\, dP_n$. (2)

However, equation (2) is not correct; the probability of winning is not simply the product of the probabilities of defeating each of the competitors. This is apparent from the bidding scenario. Each firm makes an estimate of the cost of fulfilling the contract and makes a bid based on that estimate. The higher the estimate, ceteris paribus, the higher the bid. The cost estimate is a random variable. If firm 1 makes a cost estimate which is "high" relative to the cost estimates of other firms, then clearly its ex post probability of winning is lower than if its cost estimate had been "low" relative to those of other firms. A priori, the firm has no way of knowing whether its cost estimate is "high" or "low." This renders the factorization proposed by Friedman invalid. For this factorization to be correct, the probability that the bid of firm 1 is lower than that of some specified competitor does not depend upon the relationship of the bid of firm 1 to those of other competitors. But this is not the case. The simple probability that the bid of firm 1 is lower than that of firm 3 is less than the conditional probability that the bid of firm 1 is lower than that of firm 3 given that the bid of firm 1 is lower than that of firm 2. Knowing that firm 1 bid lower than firm 2 makes it more likely that firm 1 has made a "low" cost extimate and therefore makes it more probable that the bid of firm 1 is lower than that of firm 3. Etc.

The reader can easily convince himself of the folly of the Friedman formulation by attempting to use it in the perfectly symmetrical case in which all the n bidders are mathematically indistinguishable from each other in terms of past bidding behavior and current bidding strategy. In such a situation each firm has one chance in n of being the winning bidder. Suppose, for example, n = 10. Then each firm will have 9 competitors. If the probability of winning is equal to the product of the probabilities of defeating each competing firm, then each firm must enter a bid which it feels has a probability of .775 of being lower than the bid of any specified competitor $[(.775)^9 = .1]$

But in such a symmetrical situation, the rational assumption must be that a firm's optimal bid will have only a probability of .5 of being lower than that of an equally skilled competitor who is using an identical bidding strategy. The Friedman formulation fails for the reason outlined above.

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2. R. M. Stark and R. H. Mayer, Jr. "Some Multi-Contract Decision-Theoretic Competitive Bidding Models," Opns Res 19, 469 - 483 (1971).

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