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Incentives, Information, and Winner's Curse in Construction Industry Bidding

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Abstract - This paper investigates the relationship between incentives, information and winner's curse in the bidding for construction industry contracts. The approach uses both simple Monte Carlo simulations and bidding experiments to show the effects of changing levels of information (in terms of variance) and incentive (in terms of risk share) on the winner's curse.

I. INTRODUCTION

This paper ties together three distinct and rich areas of bidding literature that are important to the understanding and dealing with these uncertainties: Incentive Contracts, Information and winner's curse.

This investigation was conducted using both simple Monte Carlo simulations and student bidding experiments. Student experiments were performed using seniors and graduate students in Civil Engineering at Portland State University. Both the simulations and the experiments were designed to investigate the relationship between varying levels of information available to bidders, the ensuing aggressiveness of the bidding (resulting in a winner's curse) and the effect of increasing the share of risk to the Owner.

A. A Brief Review of Auction and Bidding Theory

There are many surveys of auction theory in the operations research, management science and economics literature. Some of the more complete include [8, 18, 23, 34].

An auction is an economic institution designed for the exchange of goods or services, where the exact selling or purchase price of the good or service is unknown prior to the auction. The price of the exchange is established by bidding among parties wishing to either purchase or sell the good or service. Types of auctions are distinguished by the rules determined by the bid-taker. The various auction types in general use can be classified by following characteristics: highest or lowest bid, first or second price, private or common value, in combination with open (often oral) or closed (typically sealed) bidding. This paper is concerned with the most common form of bidding used in the construction industry, lowest bid, first price, common value, closed or sealed bid auctions [26].

B. First Price, Common Value, Sealed Bid Auctions

Construction bidding is generally considered and modeled as a first price, common value, sealed bid auctions.

First price and sealed bid are rules set by the bid-taker and in the public sector, are often set by law in the jurisdiction where the bidding is taking place. Common value relates to the prize for winning the contest. Construction projects are generally modeled as common value auctions due to the fact that, within certain limits, the costs of the work to be accomplished is the same for any bidder. This assumption has been questioned however [7].

The information available to bidders (and bid-takers) is another variable that should be included in any bidding model. That is, the bidders can be valuing the object based on equal albeit uncertain information or one or more bidders can possess significantly more information than the other bidders. In construction bidding, we generally assume symmetric but uncertain information regarding the value of the project is available to all prospective bidders.

C. Incentive Contract Bidding

An incentive contract or incentive contract bidding, is an attempt to design an auction where risk can be shared adequately and rationally between the bid-taker and the winning bidder. Without such a vehicle, the bidder has a great inducement to hedge against cost uncertainty [27]. This topic of research has produced a rich source of published analysis and discussion ranging from economic theory to case study analysis [1, 5, 6, 12, 19, 21, 28, 31, 33]. The basic incentive contract formulation as given by [21]:

$$\pi = \alpha p + \beta(p - C) \quad (1)$$

Where π is the profit to the contractor, α is a profit rate anticipated by the contractor, p is the bid price, β is the risk share between the bidder ($0 \leq \beta \leq 1.0$) and bid-taker and C is the actual cost after final accounting. In this formulation, the contractor's profit would be exactly equal to the "target profit" at bid time ($\pi = \alpha p$) if his bid price equals the final cost. If the final costs are less than bid, the contractor receives, $\beta(p - C)$ additional profits. If the cost exceeds the bid the contractor loses $\beta(p - C)$.

Several other authors have proposed variations on this formula. For the purpose of this paper, we will define the incentive contract formula in terms of the total cost to the bid-taker (generally the owner) as follows:

$$T(c) = \alpha C_{bid} + C_{bid} + \beta(C_{actual} - C_{bid}) \quad (2)$$

Where, α is the bidder's mark-up rate (a common method for deriving a value for the bidder's profit, overhead and other non-cost-of-work related costs). C_{bid} and C_{actual} are the estimated cost of the work at bid time and the actual cost of the work determined by a final accounting at project's end respectively (C and p above). From equation (2) we see that the bid-taker's financial risk in the case of cost over-run and gain in the case of under-run, are equal to the risk-share variable times the difference between bid and actual costs.

D. Winner's Curse

The analysis of winner's curse was first brought into the literature by Capen, Clapp and Campbell [3] in their review of high risk outer continental shelf oil and gas lease auctions. They conclude that, "In competitive bidding, the winner tends to be the player who most ever estimates true tract value." They go on to show that the "law of averages" simply doesn't apply in common value competitive bidding, because with a sufficient number of bidders, any bidder only wins if he or she over-values the item sought and in every bidding situation, some bidder will over-value the item. Which implies that competitive bidding must, over the long run, result in substantial financial losses in those industries where it is practiced.

Winner's curse has spawned a significant amount research, analyzing its existence, predicting its magnitude and guarding against it [3, 10, 16, 17, 24, 29, 30]. Winner's curse in the construction industry has been studied in [4, 7, 32].

Most of the work to date on winner's curse has focused on the bidder's perspective as opposed to the bid-taker. Here, we show the effect of the changing risk-sharing variable on winner's curse, a rule that is fully within the discretion of the bid-taker.

E. Information

A rich body of literature concerned both, directly and indirectly with its relationship to competitive bidding has been established. Much of this work is concerned with the analysis of symmetric versus asymmetric information and principal agent asymmetries [9, 11, 13, 25]. Information as it relates to winner's curse is discussed in [15]. [22] and [14] present information use in case studies of timber contracts bidding.

Here, we treat information somewhat differently. For the purposes of this paper, we equate the amount of information available to a bidder to be represented by the standard deviation of the continuous distribution of possible prices. Our purpose in equating the amount of information available to the bidder (and bid-taker) to the breadth of the distribution is to recognize that information is directly related to the range of possible prices. Complete, or 100% information should yield virtually zero variance in prices from bidders, whereas no information, 0%, should yield an infinitely large standard

deviation. Recognizing also however, that information is always greater than zero (since we know a project exists in order to bid on it) and less than complete (due to unpredictable variables such as weather.)

II. BIDDING SIMULATION STUDY

The bidding simulation is performed to test the effect of varying the amount of project information as depicted by the standard deviation of the input distributions for the project and the bidders against the risk sharing variable and mark-up. Here also, we provide a theoretical basis of comparison for the experimental data and test certain assumptions of the bidding environment.

A. Model Description

The bidding simulation portion of this study was conducted using an electronic spreadsheet to generate bids and actual costs. This process is substantially similar to an example found in [2]. In the simulation, quasi-random variates were generated for five bidders. Bid costs (" C_{bid} " in the model) for each are calculated based on the input mean and standard deviation for the given "project." The lowest of the five bidders is selected and compared with a similarly generated "cost" (" C_{actual} " in the model) for each "project."

In addition to the two cost parameters (bid cost, " C_{bid} " and project cost, " C_{actual} ") generated above, a third parameter, "mark-up" (" αC_{bid} " in the model) is included in the simulation model. Recall from Section I, the incentive formula:

$$T(C_{Bid-taker}) = \alpha C_{bid} + (1-\beta) C_{bid} + \beta C_{actual}. \quad (2)$$

In the simulation, we keep the mean value of the project constant at "300," then vary the standard deviation from "30" (or ten percent) to "180" (or sixty percent). This simulates a decreasing amount of information about the project to all bidders. The share of savings variable, β , is varied from 0 (lump sum) to 1.00 (cost plus).

Finally, knowing that construction contractors, like all businesses, are profit seekers, we assume that over time they will adjust their mark-up (αC_{bid}) to cover any average anticipated loss or winner's curse. Therefore, mark-up for each bid was calculated for the break-even point for each winning bid.

The input distribution used for this analysis was the normal distribution. However, the normal distribution for this simulation does have significant drawbacks and limitations and it is important to understand and account for these limitations.

The assumption of normality has been challenged by several researchers including, [20] and indirectly by [19]. One study [20], was able to reject the hypothesis of normality for modeling roadway projects. However, for building projects they found "the distributions of prices tendered are well modeled by normal distributions."

B. Scenario's Simulated

Three different types of scenario's were simulated: 1) where the means and standard deviations of the bidders estimated costs (C_{bid}) and the projects actual cost (C_{actual}) were equal but vary. 2) Where the standard deviation of C_{bid} remained constant, while the standard deviation of C_{actual} varied. And 3) where the standard deviation of C_{actual} remained constant, while the standard deviation of C_{bid} varied.

C. Results and Discussion

Typical results from the different scenario types are depicted in Figs. 2., 3., and 4.

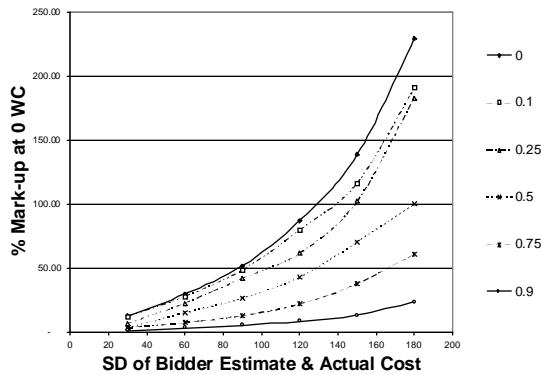


Fig. 1. Scenario 1: Both σC_{bid} and σC_{actual} vary equally

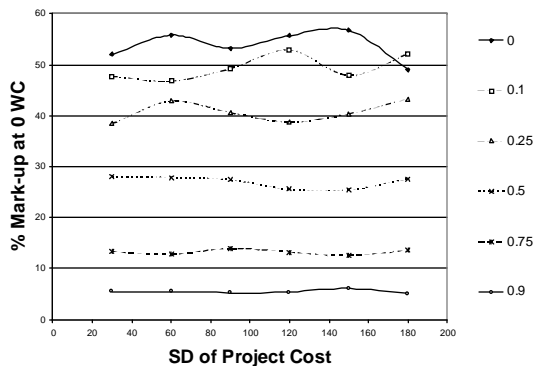


Fig. 2. Scenario 2: σC_{bid} held constant, σC_{actual} varies

The graphics presented above for Scenario's 2 and 3 are "typical" for these scenario types. Simulations were run keeping the standard deviations of one variable (C_{bid} in Scenario 2 and C_{actual} in Scenario 3) constant while the other varied from a standard deviation of 30 to 180. The graphics above are for simulations where the constant value is held at a standard deviation of 90, however, the results are substantially similar for all constant values simulated (also 30 to 180).

The graphics indicate the increase in winner's curse, as measured by the percent mark-up (α , of αC_{bid} in our model) for the different standard deviations of the x-axis variable(s). The different lines graphed indicate different levels of risk share (β), beginning at the bottom of each Fig. with a $\beta=0.90$

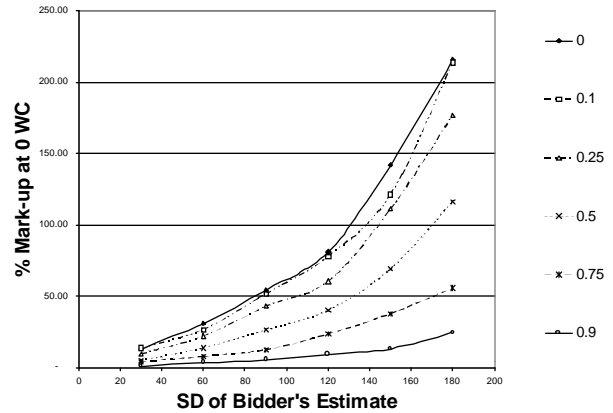


Fig. 3. Scenario 3: σC_{actual} constant, σC_{bid} varies

and proceeding up in order, 0.75, 0.50, 0.25, 0.10 and 0.0. The data for cost-plus, or $\beta=1.0$ is not graphed because it would simply equal zero for all values.

The results indicate that winner's curse and subsequently, mark-up, in the presence of constant risk share, are most sensitive to the standard deviation of the bidder's estimated costs (C_{bid}). This is indicated most graphically in Scenario 3, (Fig. 4) which represents a constant variability in the actual cost and increasing variability in the bidders estimated cost. These conditions might occur when the an owner creates variability in actual costs outside of the actual scope of work, while offering the contractor varying levels of information reflected in changing standard deviations of C_{bid} . From Fig. 4 we conclude that as information becomes less reliable (that is, as the standard deviation of C_{bid} increases), the owner must increase the risk sharing variable to keep winner's curse and subsequent bidder mark-up within reasonable levels.

Fig. 3 is characteristic of common and constant variability in C_{bid} , while C_{actual} 's variability is allowed to increase. This might be interpreted as a relatively well-defined (or at least commonly defined) project scope, but ill defined owner management practices which lead to highly variable costs. In this case, the risk sharing variable defines the winner's curse and sets the contractor's required mark-up for various levels of bidder variability. (Fig. 3 depicts a bidder variability or standard deviation of 90. For smaller standard deviations, the effect is less pronounced and the opposite is true also.)

Our analysis of Fig.'s 3 and 4 lead us to conclude the primary cause for the shape of the graphs in Fig. 2 are owing to the effects discussed for Fig. 4. That is, the changing variability in C_{bid} , which reflects differences in information offered the bidders.

The weakness of our normality assumption observed earlier would be expected to aggravate the winner's curse effect in these simulations. Our empirical study found that real contractor bids were more closely distributed about the mean than the normal function would have predicted. Therefore, we would not expect as many low bids as were generated by the simulation. However, we would expect actual data to take the same general shape as the curves depicted in Fig.'s 2 and 4.

III. BIDDING GAME

An experiment was performed to simulate the construction-bidding environment with varying amounts of information and changing risk sharing. Seniors and graduate students enrolled in the Civil Engineering department at Portland State University performed the experiment.

A. Description

This experiment consisted of twelve successive bids for jars of candies. Students were given an opportunity to examine each jar prior to the start of bidding. They were told that the jars contained a number of candies drawn from one of three random normal distributions. Each distribution had a mean of 300 and one of three standard deviations (σ). Each bid was conducted under one of four risk-sharing rates (β 's). The following table shows which β and σ applies to each bid, by number.

TABLE I

	$\sigma = 100$	$\sigma = 50$	$\sigma = 25$
$\beta = 0.00$	Bid 1	Bid 2	Bid 3
$\beta = 0.25$	Bid 4	Bid 5	Bid 6
$\beta = 0.50$	Bid 7	Bid 8	Bid 9
$\beta = 0.75$	Bid 10	Bid 11	Bid 12

Each bidder was asked to estimate and bid both C_{bid} and αC_{bid} . After each student completed his or her bid, the lowest bids were announced and read aloud. Next, the actual amount of candies (C_{actual}) for that jar was revealed. Each bidder then calculated his actual profit or loss based on equation (2). The lowest non-zero bid was awarded a small bag of candies (not the jar full, however). It is assumed that bids that result in losses greater than the bid fee, αC_{bid} , would be pulled before consummating a contract. Bids proceeded in order from 1 to 12.

B. Results

The students were inexperienced bidders but relatively fast learners. The students, on average, underestimated C_{actual} on every bid. The lowest bidder underestimated C_{actual} by 183 on average and suffered losses on average of 45.7 (meaning that, on average, the low bidder was forced to pull his or her bid).

As bidding progressed students learned that as the risk share increased, that the estimated cost became less significant. This in-turn caused bidding to become more aggressive (meaning lower bids) as the share of savings variable increased, as shown below:

Estimated & Actual Cost vs Beta

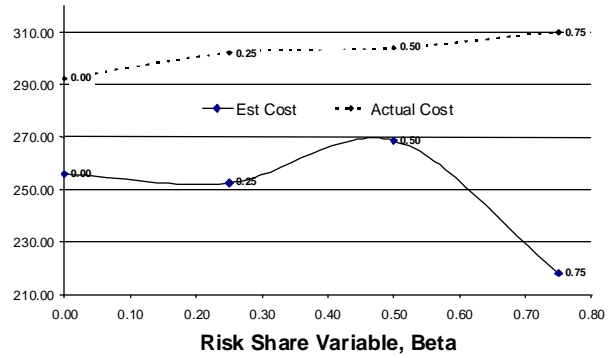


Fig. 4. Averaged estimated cost bids and actual costs for each level of risk share: beta (β).

Interestingly, the student bidding more closely resembled a normal distribution than did the empirical study of real bids. However, the student bids did exhibit the same central tendency, as did the actual construction bids, just not as pronounced. Checking for normality again we were similarly able to reject the normality hypothesis.

C. Discussion

This experiment was designed to test bidders response to changing levels of information (as represented by standard deviations) and risk (as represented by β 's.) There were two principal drawbacks to this experiment, and in particular choice of participants: (1) the relative lack of experience or knowledge of bidding, and (2) the relative complexity of the game. In spite of these drawbacks, the students performed substantially as we would have predicted, given the outcome of the simulated bidding contests.

Students consistently underestimated the actual cost. This was particularly evident among the lowest bidders. An average of the lowest ten bidders for each bid shows a clear pattern of consistent underestimating.

One effect that was perhaps not predicted from the simulation data was game competition aspect of the bid. Note in both Fig.'s 5 and 6, the reduced estimated costs for bids 11 and 12 (both β 's = 0.75). This occurred when some bidders realized that they could bid the minimum possible value for C_{actual} , based on the given distributions¹, then adjust their fee to compensate for the difference in costs times the risk share, β . For instance, when $\beta = 0.75$, the bidder knows he only suffers 25% of the difference between estimated and actual costs. Knowing that the minimum possible cost is 2σ below the mean and the maximum is 2σ above the mean, the bidder can be assured of positive profits if his fee exceeds σ ($0.25 * 4\sigma$.) The game then becomes estimating the maximum

¹ Students were given the actual distribution of all C_{actual} 's for each of the three distributions.

anticipated actual cost, based on the amount of risk the bidder is willing to accept. The effect on the bidding was to increase fees while simultaneously decreasing estimated costs. However, as we may have expected, the bidding, due mainly to the reduction in estimated costs, became more aggressive as time went on and bidder risk decreased as share of savings increased

IV. SUMMARY

This paper investigated the relationship between three important areas of competitive bidding: incentives, information and winner's curse. The study included both Monte Carlo simulations and bidding experiments. We found a number of relationships that exist between amount of information available to bidders (in the form of standard deviation of the estimates) and winner's curse. As the amount and or quality of information becomes less reliable,

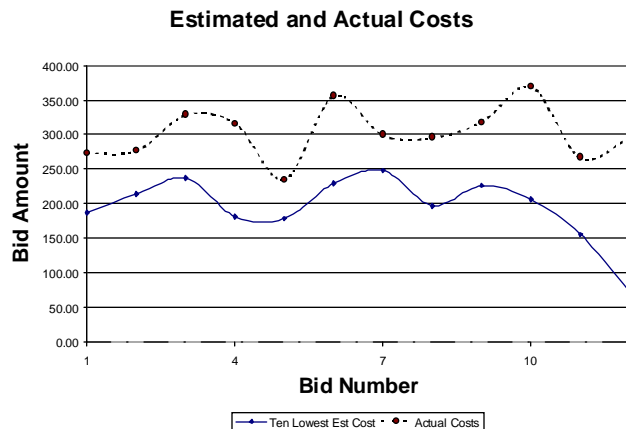


Fig. 5. Ten lowest bidders Averaged Estimated Cost Bids and Actual Costs for each Bid, by Bid Number.

the magnitude of mark-up required to off-set the winner's curse increases, and that this relationship is not linear.

We find that, winner's curse is most sensitive to the information offered the bidder. And, if the amount or quality of information is not controllable by the bid-taker, then the bid-taker can control the magnitude of winner's curse and resulting mark-up by increasing the risk sharing variable.

The student bidding experiments did perform much our simulations had predicted. One significant deviation from the expected behavior occurred toward the end of the experiment. Some bidders started to better understand the rules of the game as risk share increased to 75% for the owner. Under these conditions in the last several bids, the winning bidders reduced their estimated costs to the minimum possible then covered the anticipated difference between estimated and actual cost by increasing their fee. The lower the anticipated actual cost, the lower the fee required is. This differs from the normal bidding process which seeks to minimize the difference

between actual and estimated costs and minimize the fee in order to reduce the overall bid.

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