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Tenders with Different Risk Preferences in Construction Industry

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Abstract

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JEL Classification: JEL: D44, L74

Keywords: Auction, tender, uncertainty, preference, construction industry

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1 Introduction

Competitive sealed-bid auctions are commonly used in the construction industry. Its basic rules are that all the qualified tenderers should quoted price sealed, bids must be submitted by a fixed deadline and opened publicly, and finally the lowest-price or second lowest-price tenderer will win the bid. Previous studies suggest the object for sale in most auctions possess both private and common value elements (e.g., Goeree and Offerman [1] [2], Klemperer [3], and Laffont [4]). In contrast, Dyer and Kagel [5] argued construction contract bidding was usually treated as a common value auction. What makes the auction interesting is that bidders have different estimates of the true value at the time they bid. If bids decrease with decreasing cost estimates, the low bidder faces an adverse selection problem, as he/she wins only when he or she has one of the lowest estimates of the cost of construction. Unless this adverse selection problem is accounted for in bidding, the low bidder is likely to suffer from a 'winner's curse', winning the item but making below normal or even negative profits. For competitive bidding auction, Klemperer [6] also investigates the vulnerability of auction mechanism to collusion, and shows the collusion is very likely to deter entry into an auction. Further, Caillaud and Jehiel [7] point out that collusion among buyers eliminates bidding competition despite informational asymmetries in standard auctions. Although the bid auction theories rooted from market-based economy receive wide attentions, the market still shows the worries and qualms for bidders take aleatory behavior to make the enforcement of contract delayed in transition countries.

For example, in recent years, some tenderers utilize the deficiency of law and regulation from government and try to seek profit for themselves by unwarrantable action after they win the bid in Chinese construction market. As a result, some perilous buildings and bridges constructed threaten against the public security. Because conventional bid auction theory is constructed in market-developed countries and some transition countries from plan to market economy have no perfect market and price mechanism, these theories and methods cannot fit the situation in transition countries. Thus, a problem researchers face is that if a general model can be constructed to cover different behavioral paradigms. This study generalizes competitive sealed-bid auction theory to allow for different risk preferences in bids.

Since economic research on auction and competitive bidding began in 1961 with Vickrey's [8] seminal work, most of the early auction literature follows the standard bid auction model from McAfee and McMillan's [9] insight into bid auction theory (e.g., Rothkopf [10], Wilson [11], Milgrom [12], Maskin and Riley [13] [14]). Numerous models are almost based on the following several common assumptions: (A1) All tenderers are risk-neutral, (A2) Every tenderer has the independent information of estimating the bid, (A3) Payment is just the function of price quoted, (A4) The distribution of tenderers' price quoted is symmetric. In previous effort, McAfee and McMillan [11] generalize auction theory, based on the results shown on optimal auctions with risk-averse bidders of Maskin and Riley [15], Matthews [16,17], Moore [18], Harstad, Levin and Kagel [19], to allow for uncertainty about the number for bidders (hereafter numbers uncertainty). They found in a first-price sealed-bid auction with independent private values, if the number of bidders is unknown and bidders have constant absolute risk aversion (CARA), then the expected revenue to the seller is greater if the actual number of bidders is concealed rather than revealed. Matthews [20] extends McAfee and McMillian's result to the case in which buyers have decreasing absolute risk aversion (DARA), and suggests that if bidders are risk neutral, the expected revenue to the seller is the same whether the actual number of bidders is revealed or concealed. However, the bidders prefer a policy of revelation when they have decreasing absolute risk aversion, and a policy of concealment when they have increasing absolute risk aversion. Furthermore, Matthews shows that some of the results change when the assumption of constant absolute risk aversion is relaxed. Eso and White [21] find precautionary bidding behavior can make DARA bidders perfect bidding in a common values setting to bidding in a private values one when risk-neutral or CARA bidders would be indifferent. Waehrer, Harstad and Rothkopf [22] analyze the preferences of a risk-averse seller over the class of "standard" auctions with symmetric and risk-neutral bidders. The results suggest that all risk-averse sellers prefer a sealed-bid first-price auction with an appropriately set reserve price to any other standard auction. Delatas and Engelbrecht-Wiggans [23] consider a common value auction in which a "naive" bidder (who ignores the winner's curse) competes against a fully rational bidder. They show that the naive bidder earns higher equilibrium profits than the rational bidder when the signal distribution is symmetric and unimodal.

Although the standard bid auction model offers an advantage for bid theory research, the basic assumption: "A1 all tenderers are risk-neutral" is not very consistent with reality and limited in use. In existing literature, scholars mainly deal with the bid behavior and strategy in situation of tender with unchanged risk-taking preferences: risk-neutral or risk- averse, lacking of the research of bid behavior and strategy with three different kinds of risk-taking tenderers exist at one time. As Smith and Levin [24] argue, although previous papers have considered the implications of endogenous entry by risk-neutral bidders (see Engelbrecht-Wiggans [25], Hausch and Li [26], Levin and Smith [27], Maskin and Riley [28], Samuelson [29]), the sensitivity of results to risk preferences has not been examined. Our surveys on bid behavior showed that in Chinese bidding market, all these three kinds of risk-taking preferences exist at the same time. The researches of west scholars based on the developed market economy and consummate law system, they cannot meet the needs of practices when these models are applied to bid auction in transition countries. As Rothkopf and Harstad [30] argued, sophisticated bidders in many auction markets profess to have little use for bidding theory. Design issues and objectives, as well as behavioral assumptions, tend to segregate most theoretical contributions in the literature from usefulness to practitioners. For example, a behavioral assumption that underlying probability distributions generating bidders' information are commonly known is ubiquitous in the literature and often untenable in practice. In our study, these assumptions are relaxed to cover different three risk preferences mentioned above and further a general bid auction model is gained.

The remainder of the paper is organized as follows. Section 2 derives the estimate made in bid. Section 3 presents the general model with different risk preferences. Section 4 investigates the implications of extended bid auction model for competitive sealed-bid auction theory and practice and section 5 concludes.

2 Price Estimate with Different Risk Preferences

Engelbrecht-Wiggans [31] argues that different players have different utility functions. More often, the true characteristics of an object are not known. Different players may observe different information and form different estimates of the object's true value. Consider a tender auction where n qualified tenderers compete for a single construction object such as a public installations contract, drilling rights for oil etc. On account of different estimated cost for different tenderers, the tenderer i's valuation of the object is denoted by c_i. We assume symmetric tenderers, where each tenderer's private value is represented by an independent identically draw from the same distribution of private values, denoted by distribute function F on interval $[c_l, c_h]$, $c_l = \min\{c_i\}$, $c_h = \max\{c_i\}$ $(i = 1,2,3,\cdots,n)$, c_i is private value for the object known only to the tenderer i. Following McAfee & McMillan's view [9], the tenderers are assumed to be risk-neutral, so the estimated cost c_i is not influenced by uncertain factors. This assumption is not completely identical with the reality. Samuelson [32] argues that uncertainty factors tenderers encounter always concern the cost of the object. In the real construction tendering project, the tenderers with different risk-taking preferences compete for a construction object at one-shot bid auction time. If the tendering auction contract is the total price contract, except the certain factors for the cost price, the uncertain factors should also be taken into account.

Actually, the governments of Britain and U.S. ask the tenderers to consider the effects of uncertain factors when quoting the price. Risk brought by the uncertain factors in construction object may result in different outcomes. Risk is characterized by impersonality, but there exist differences among the tenderers' risk valuations. As the attitude to the uncertain factor depends on the tenderer's risk-taking preferences, McAfee and McMillan [33] point out that in any specific bidding environment, the model builder for bid auction should pay attention to tenderers' risk-taking preferences.

The tenderer *i*'s estimation for uncertain factors of the construction is denoted by $\overline{C}_i$. The property of $\overline{C}_i$ and the degree that $\overline{C}_i$ influences the valuation c_i, depend on that tenderer's risk preferences. With different tendering behavior and strategy, for risk-averse tenderers, it's possible that $\overline{C}_i$ is considered to be more latent cost than the latent profit and increase the quote price. Conversely, risk-seeking tenderers consider $\overline{C}_i$ to be more latent profit than the latent cost and decrease the quote price while the risk-neutral tenderers consider the probability of $\overline{C}_i$ for latent profit is same to the probability of $\overline{C}_i$ for latent cost and valuations are not affected by $\overline{C}_i$. Thus, the valuation c_i is made up of three parts: first is c_i affected by positive $\overline{C}_i$, second is c_i affected by negative $\overline{C}_i$ and third is c_i not affected by $\overline{C}_i$. Thus, the tenderee's payment to the winning tenderer *i* for the construction object can be given by

$$p_i = c_i + \delta \overline{c}_i \qquad (1)$$

Where p_i denotes the tenderer i's payment, $\delta \in [-1,1]$, represents the tenderer i's risk-taking preference index with three cases,

(i) $\delta \in [-1,0)$, δ presents risk-seeking tenderer's degree of seeking risk.

(ii) $\delta \in (0,1]$,δ presents risk- averse tenderer's degree of avoiding risk.

(iii) $\delta = 0$ means the tenderer is risk-neutral.

3 Equilibrium Strategies and Revenues

In extended standard bid auction model, the assumption "A1. tenderers are risk-neutral" would be change into "A'_1. tenderers have different risk-taking preferences". That means all three kinds of risk-taking preferences tenderers compete for the construction contract. In this study, other three assumptions A2, A3, A4 still remain unchanged and hold out for all the tenderers when the tenderee is considered to be risk-neutral.

For a construction project, tenderee will hope the price of the contract as low as possible because the tenderee's payment for construction object should be reclaimed by contract with the project being finished. Otherwise, tenderee will lose out on the construction project.

Lemma 1. For tenderer i's quote price b_i, the n-tuple of strategies ($B(\cdot), B(\cdot), \ldots, B(\cdot)$), where

$$B(p_i) = b_i \qquad (2)$$

is a Nash-equilibrium of the competitive sealed-bid auction.

Proof. If the tenderer i wins the contract with the quote price b_i, the price P^C of the contract is given by

$$P^C = b_i \tag{3}$$

Assume tenderer *i* speculates that other tenderer j's function of quote price is strictly increase with his cost. Thus, there exists a function *B* of quote price for tenderer *i* such that

$$b_i = B(p_i) \tag{4}$$

Following Maskin and Riley's view[13][14], the symmetry Nash-equilibrium exists under the condition.

According to Lemma 1, we derive the equilibrium tendering functions for our model. Milgrom and Weber [34] characterize the equilibrium for standard auctions when bids are based on a univariate statistic. The explicit characteristic of the equilibrium allows us to study interesting economic phenomena such as the effects of uncertainty, public release of information and competition on efficiency and revenues (see, Goeree and Offerman [1]). We can assume the set of other tenderer's tendering strategies (except the tenderer i) to be

$$B = \{B(p_1), B(p_2), ..., B(p_{i-1}), B(p_{i+1}), ..., B(p_n)\} \tag{5}$$

Theorem 1. Given $B(\cdot)$ is a strictly increasing function, the tenderer *i*'s valuation c_i of the object is independent identically drawn from the same distribution of private values, denoted by distribute function F on interval $[c_l, c_h]$, $c_l = \min\{c_i\}$, $c_h = \max\{c_i\}$ $(i = 1,2,3,\cdots,n)$. If tenderers are symmetric, then the relationship among quote price, risk preference index and tenderer *i*'s valuation can be represented by

$$b_i = c_i + \frac{(c_h - c_i)}{n} + \frac{n-1}{n}\delta\overline{c_i} \tag{6}$$

Proof. Given $B(\cdot)$ is a strictly increasing function, the probability p_i of tenderer i quoting the lowest price can be given by

$$p_i = prob(b_i < B(p_j)) \text{ (j=1,2,…i-1,i+1,…,n)} \tag{7}$$

For $p_i = B^{-1}(b_i)$, where B^{-1} is the inverse function of *B*, the probability of tenderer i winning the bid is equal to the probability of other (n-1) tenderers j lost the bid. So the maximum profit that the tenderer i expects with the quote price b_i will be $\max_{b_i}(E\prod^i)$.

By equation (1) and lemma 1, we can obtain

$$\begin{aligned}
E\prod^i &= [b_i - p_i]\prod_{j\neq i}[prob(B(p_j) > b_i)] \\
&= [b_i - p_i]\underbrace{[1-prob(B^{-1}(b_i))][1-prob(B^{-1}(b_i))]\cdots[1-prob(B^{-1}(b_i))]}_{(n-1)个} \\
&= [b_i - c_i - \delta\overline{c_i}][1-prob(B^{-1}(b_i))]^{n-1} \\
&= [b_i - c_i - \delta\overline{c_i}]\underbrace{[1-F(B^{-1}(b_i))][1-F(B^{-1}(b_i))]\cdots[1-F(B^{-1}(b_i))]}_{(n-1)个} \\
&= [b_i - c_i - \delta\overline{c_i}][1-F(B^{-1}(b_i))]^{n-1}
\end{aligned} \tag{8}$$

To maximize $(E\prod^i)$, equation (8) should satisfy the first-order necessary condition, i.e.,

$$\frac{\partial E\pi_i}{\partial b_i} = [1 - F(B^{-1}(b_i))] - (b_i - c_i - \delta \overline{c_i})(n-1)F'(B^{-1}(b_i))B'^{-1}(b_i) = 0 \quad (9)$$

For B(.) satisfied the symmetric Nash-equilibrium condition (according to lemma 1.), every rival of tenderer i is as sensible as tenderer *i* and anyone who estimate the same price quote the same price. Thus, we can obtain

$$b_i = B(p_i) = B(c_i + \delta \overline{c_i}), \quad B^{-1}(b_i) = p_i = c_i + \delta \overline{c_i} \quad (10)$$

While substituting equation (10) in equation (8), we get:

$$\begin{aligned}&[1 - F(p_i)] - (b_i - p_i)(n-1)F'(p_i)\frac{\partial p_i}{\partial b_i} \\ &= [1 - F(c_i + \delta \overline{c_i})] - (b_i - c_i - \delta \overline{c_i})(n-1)F'(c_i + \delta \overline{c_i})\frac{\partial(c_i + \delta \overline{c_i})}{\partial b_i} \quad (11) \\ &= 0\end{aligned}$$

By the distribution of c_i, we have

$$F(p_i) = F(c_i + \delta \overline{c_i}) = \frac{(c_i + \delta \overline{c_i}) - c_l}{c_h - c_l} \quad (12)$$

Putting equation (12) in equation (11) gives

$$[1 - \frac{(c_i + \delta \overline{c_i}) - c_l}{c_h - c_l}] - (b_i - c_i - \delta \overline{c_i})(n-1)\frac{1}{c_h - c_l}\frac{1}{\frac{\partial b_i}{\partial(c_i + \delta \overline{c_i})}} = 0$$

$$\Rightarrow [\frac{c_h - c_i - \delta \overline{c_i}}{c_h - c_l}] - (b_i - c_i - \delta \overline{c_i})(n-1)\frac{1}{c_h - c_l}\frac{1}{\frac{\partial b_i}{\partial(c_i + \delta \overline{c_i})}} = 0$$

$$\Rightarrow [c_h - c_i - \delta \overline{c_i}]\frac{\partial b_i}{\partial(c_i + \delta \overline{c_i})} - (b_i - c_i - \delta \overline{c_i})(n-1) = 0$$

$$\Rightarrow \frac{\partial b_i}{\partial(c_i+\delta\overline{c_i})}-\frac{(b_i-c_i-\delta\overline{c_i})}{(c_h-c_i-\delta\overline{c_i})}(n-1)=0$$

$$\Rightarrow \frac{\partial b_i}{\partial(c_i+\delta\overline{c_i})}-\frac{(n-1)}{(c_h-c_i-\delta\overline{c_i})}b_i=\frac{(n-1)}{(c_h-c_i-\delta\overline{c_i})}(-c_i-\delta\overline{c_i}) \qquad (13)$$

Solving differential equation (13) for c_i, we have

$$\begin{aligned} b_i &= e^{\int\frac{n-1}{c_h-c_i-\delta\overline{c_i}}d(c_i+\delta\overline{c_i})}\{\int[-\frac{(n-1)(c_i+\delta\overline{c_i})}{c_h-c_i-\delta\overline{c_i}}e^{\int-\frac{(n-1)}{c_h-c_i-\delta\overline{c_i}}d(c_i+\delta\overline{c_i})}]d(c_i+\delta\overline{c_i})+\varepsilon\} \\ &= e^{\ln(c_h-c_i-\delta\overline{c_i})^{1-n}}\{\int[-\frac{(n-1)(c_i+\delta\overline{c_i})}{c_h-c_i-\delta\overline{c_i}}e^{\ln(c_h-c_i-\delta\overline{c_i})^{1-n}}]d(c_i+\delta\overline{c_i})+\varepsilon\} \\ &= (c_h-c_i-\delta\overline{c_i})^{1-n}\{\int[-\frac{(n-1)(c_i+\delta\overline{c_i})}{c_h-c_i-\delta\overline{c_i}}(c_h-c_i-\delta\overline{c_i})^{n-1}]d(c_i+\delta\overline{c_i})+\varepsilon\} \\ &= (c_h-c_i-\delta\overline{c_i})^{1-n}\{(c_i+\delta\overline{c_i})((c_h-c_i-\delta\overline{c_i})^{n-1})+\frac{(c_h-c_i-\delta\overline{c_i})^n}{n}+\varepsilon\} \\ &= (c_i+\delta\overline{c_i})+\frac{(c_h-c_i-\delta\overline{c_i})}{n}+\varepsilon(c_h-c_i-\delta\overline{c_i})^{1-n} \end{aligned} \qquad (14)$$

In equation (14), for n=1, b_i is equal to c_h, from the boundary condition we can get $\varepsilon=0$. Thus, we have

$$\begin{aligned} b_i &= (c_i+\delta\overline{c_i})+\frac{(c_h-c_i-\delta\overline{c_i})}{n} \\ &= c_i+\frac{(c_h-c_i)}{n}+\frac{n-1}{n}\delta\overline{c_i} \end{aligned} \qquad (15)$$

The intuition behind this result is as follows. The earliest bidding models (see Friedman [35]) assumed or calculated a probability distribution, F(x), for the best competitive bid, x, and then had the bidder choose the bid, b, that maximized his expected profit, (v-b)F(b), relative to a known expected value, v, for the auctioned asset. But here an extended bidding model consider the tenderers' risk preferences. Although the number of tenderers increasing results in lowering of tenderers' quote price for construction object, the differences among risk preference indexes make the degree of lowering of quote price distinct. To investigate the distinction, we analyze the characteristics of equation (15) in next section.

4 Discussion

The tenderer *i* who quotes the lowest price b_i will win the bid in the lowest-price sealed construction tender. This extended model is efficient for it is characterized by rational tendering. Tenderer i who wins the bid quote the price for the maximum profit. If the tenderer doesn't take part in the tendering, his profit will be zero. Otherwise, tenderer i's profit will be

$$
\begin{aligned}
E\pi_i &= (b_i - c_i - \delta\overline{c_i})[1 - F(B^{-1}(b_i))]^{n-1} \\
&= [c_i + \frac{(c_h - c_i)}{n} + \frac{n-1}{n}\delta\overline{c_i} - c_i - \delta\overline{c_i}][1 - F(B^{-1}(b_i))]^{n-1} \\
&= \frac{(c_h - c_i - \delta\overline{c_i})}{n}[1 - F(B^{-1}(b_i))]^{n-1}
\end{aligned}
\tag{16}
$$

We will analyze the effect of different risk preferences on quote price. In equation (15), $\delta \in [-1,1]$ presents the tenderer *i*'s risk-taking preference index, i.e., the degree of seeking risk or avoiding risk.

First, if the tenderer *i* is risk-neutral, then $\delta = 0$. We can get the quote price according to (16):

$$b_i = v_i + \frac{(c_h - v_i)}{n} \tag{17}$$

It is nearly identical to the standard bid auction model.

Second, if the tenderer *i* is risk-seeking, then $\delta \in [-1,0)$. When $\delta \to -1$, it suggests that tenderers will lower their quote price avariciously so as to win the construction contract. According to equation (15), we can get the quote price:

$$
\begin{aligned}
b_i &= c_i + \frac{(c_h - c_i)}{n} + \frac{n-1}{n}\delta\overline{c_i} \\
&= c_i + \frac{(c_h - c_i)}{n} - \frac{n-1}{n}|\delta|\overline{c_i}
\end{aligned} \tag{18}
$$

With other parameters unchanged, the risk-seeking tenderer will decrease the quote price b_i through increasing the degree of seeking risk δ.

Third, if the tenderer i is risk-averse, then $\delta \in (0,1]$. When $\delta \to 1$, tenderers tend to quote the price scrupulously. Because of the asymmetric information, the tenderers hope to win the bid on one hand but increase the quote price for considering the risk on another hand. By Equation (15), we can get the quote price:

$$
\begin{aligned}
b_i &= v_i + \frac{(c_h - v_i)}{n} + \frac{n-1}{n}\delta\overline{v_i} \\
&= v_i + \frac{(c_h - v_i)}{n} + \frac{n-1}{n}|\delta|\overline{v_i}
\end{aligned} \tag{19}
$$

With other parameters unchanged, the risk-averse tenderers will increase the quote price b_i through increasing the degree of avoiding risk δ.

Analysis above shows that risk-seeking tenderers are more likely to win the construction contract in one-shot construction tender auction. But in real-world construction bid auction, selecting a risk-seeking tenderer will increase the latent risk of the risk-neutral tanderee than that of selecting other kinds of tenderers. If the risk-seeking tenderer who wins the bid, fails to fulfill the contract and cannot compensate for the loss brought by fell back or has any lawsuit entanglement with the tanderee, it’s possible that the actual loss of construction contract failure is taken by the tenderee. This is an acute failure transition countries encounter in practical construction bid auction. Both government and tenderee worry about the contract failure caused by low price competition for the construction object. A further research, on tendering model for different risk-taking preference with changing environment, should be made to find a new efficient mechanism and design on construction bidding, in order to control the risk in performing the contract and the protection of the tenderees' interests.

5 Conclusions

This study analyzes the effect of different risk-taking preferences on quoting the price. We assume that risk-averse tenderers would consider the probability of uncertain factors to be latent cost is bigger than the probability of it to be latent profit, and the risk-seeking tenderers would consider probability of uncertain factor to be latent profit is bigger than the probability of it to be latent cost while the risk-neutral tenderers would consider the probability of uncertain factor to be latent profit is same to the probability of it to be latent cost.. Based on these assumptions, this paper gives a tender model in lowest-price sealed bid auction for different risk-takings tenderers in construction industry. The results suggest that in a lowest-price sealed bid, risk-averse tenderers will quote a higher price, and risk-seeking tenderers will quote a lower price when risk-neutral tenderers will quote a middle price. However, the risk-seeking tenderers are more likely to win the construction contract.

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