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Decision Support

Behavioral models for first-price sealed-bid auctions with the one-shot decision theory

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ABSTRACT

We build an auction model with the one-shot decision theory which describes the process of a bidder deciding his/her bidding price in first-price sealed-bid auctions. The decision making procedure involves two steps: First, for each of his/her possible bidding prices, the bidder examines every possible highest bidding price provided by the other bidders and chooses one as a focus point of this bidding price of him/her. Then, the bidder determines such a bidding price as the optimal one that generates the best outcome when its focus point occurs. The optimal bidding price can be obtained and two common phenomena in auction markets: throwing away and overbidding are well explained.

1. Introduction

In the first-price sealed-bid auction, all bidders simultaneously submit their bidding prices, the bidder who offers the highest bidding price acquires the object. If the bidder fails in the auction, then his/her payoff is 0; if he/she wins, then the payoff is his/her own valuation (of the object) minus his/her bidding price. There is a rich literature on the first-price sealed-bid auction due to its several attractive features, such as the efficiency in allocating commodities, resistance to collusive behavior and encouragement of participation. Theoretically, properties of optimal bidding prices have been examined under several different circumstances, such as costly entry (Levin & Smith, 1994), mixed bidder population (Lorentziadis, 2012), and packages of items (Drexl, Jornsten, & Knof, 2009). Recently, multi-period auctions (Katehakis & Puranam, 2012a, 2012b; Puranam & Katehakis, 2014), auctions with capacity constraints (Chaturvedi, 2015) and online reverse auctions (Pham, Teich, Wallenius, & Wallenius, 2015) are examined and auction approaches have been utilized in supply chain management (Budde & Minner, 2014; Cheng, 2011; Lorentziadis, 2014).

Traditionally, the first-price sealed-bid auctions are formulated as Bayesian games: each bidder knows his/her own valuation exactly but only knows the probability distribution of his/her opponents' valuations. The classical equilibrium bidding price, namely the Risk Neutral Bayesian-Nash Equilibrium (hereafter RNBNE), is also derived (Vickrey, 1961). However, experimental evidence shows that RNBNE cannot well account for the actual behavior of a bidder. Generally speaking, there exist two major deviations. One is that bidders with low valuation tend to 'throw away': Cox, Smith, and Walker (1988, 1992) point out the throwing away phenomenon, that is, some subjects with low valuation in first price auction experiments tend to bid randomly. The other is that bidders with high valuation tend to overbid – bid above the RNBNE (Cox, Roberson, & Smith, 1982).

In this paper, we propose a behavioral model for the individual bidder to model his/her decision-making procedure in the first-price sealed-bid auction. There are two steps: In the first step, for his/her each possible bidding price, say, x, the bidder evaluates every highest bidding price provided by the other bidders, say y, considering the probability of y and the outcome generated by x and y; amongst all possible highest bidding prices provided by the other bidders, the bidder chooses one which yields a relatively bad outcome with a relatively high probability. It reflects the conservative attitude of the bidder. We call such a y the focus point of the bidding price x. In the second step, the bidder evaluates each bidding price based on its focus point and determines the optimal one which can generate the best outcome when its focus point occurs. Clearly, in our model, a bidder determines his/her bidding price based on one chosen scenario (one highest bidding price offered by the opponents).

Our model is different from the existing auction models in which each bidding price is evaluated by the weighted average of all possible highest bidding prices provided by the other bidders (the expected utility). Our model reflects the scenario-based thinking which is the core argument of the one-shot decision theory (Guo, 2011). The one-shot decision theory argues that a decision

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maker is boundedly rational (Simon, 1957) due to his/her bounded attention (Masatlioglu, Nakajima, & Ozbay, 2012). Thus, he/she makes a decision only based on the most appropriate scenario of him/her without taking into account all scenarios simultaneously. The one-shot decision theory has been utilized for analyzing a duopoly market of a new product with a short life cycle (Guo, Yan, & Wang, 2010), newsvendor problems for innovative products (Guo & Ma, 2014) and multistage one-shot decision making problems (Guo & Li, 2014).

Our model is a non-equilibrium model because we analyze the auction from the perspective of a bidder. Another well-known non-equilibrium model – Level K model (Nagel, 1995; Stahl & Wilson, 1995), is also utilized to analyze first-price sealed- bid auctions (e.g. Crawford & Iriberri, 2007). Simply speaking, the Level K model partitions bidders according to levels of reasoning: a level-0 bidder bids randomly and the bidding price of a level-k bidder is the best response to that of a level-$(k-1)$ bidder. Different from the Level K model, we assume that all bidders are homogeneous in the reasoning ability, in other words, each bidder thinks only one step. As auction is a relatively complex game, it is more likely for a bidder to think only one step. Also, we argue that the number of reasoning step 'k' is arbitrary and makes the problem untraceable.

This research contributes to the literature of auction models in the following two dimensions. First, we build a behavioral model to delineate the decision-making process of a bidder determining the bidding price in the first-price sealed-bid auction; the optimal bidding price is obtained and a comparative statics analysis is made. Second, we gain the insights into the behavior of the bidders and explain two common phenomena in auction activities: overbidding and throwing away; especially, to the best of our knowledge, our model is the unique one which can account for throwing away.

This paper is organized as follows: In Section 2, first-price sealed-bid auction models with the one-shot decision theory are proposed for two bidders case; in Section 3, the proposed models are extended to N bidders case and overbidding and throwing away phenomena are explained; in Section 4, concluding remarks are made.

2. Two bidders' first-price sealed-bid auction models with the one-shot decision theory

To facilitate the understanding of our models, let us begin with examining the two bidders case. For bidder $i \in \{1, 2\}$, the set of his/her bidding prices is $[0, v_i]$ where v_i is his/her valuation of the auctioned subject, which is an independent private value; bidder i also knows the probability density function of his/her rival's bidding price B_j, denoted as $p_i(b_j)$ where b_j is a bidding price offered by the other bidder. For simplicity, we assume that v_i takes a value from $[0, 1]$ and B_j is a random variable over $[0, 1]$. Given $p_i(b_j)$, we have

$$\pi_i(b_j) = p_i(b_j)/\max_{b_j} p_i(b_j), \tag{1}$$

which is called the relative likelihood degree of b_j.

In our model, when we think about the outcome of each bidding price, we take into account not only the gain achieved but also the regret caused after knowing the result. Considering the effect of regret on bidders' behaviors is not new. It is initially examined by Engelbrecht-Wiggans (1989) and further studied by Engelbrecht-Wiggans and Katok (2007, 2009), and Filiz-Ozbay and Ozbay (2007). The winner in a first-price sealed-bid auction is the bidder with the highest bidding price. However, it is always the case that the winner finds himself/herself bid too high after the revelation of all the other bidders' bidding prices. In this situation, we say that the winner suffers from 'winner's regret'. In contrast, after an auction, a loser may find that the winner's bidding price is below his/her valuation of the auctioned object. In this case, the loser actually missed an opportunity to gain, and we say that the loser suffers from 'loser's regret'. The evaluation function is given as follows:

$$f_i(b_i, b_j) = \begin{cases} (v_i - b_i) - k_{i,1}(b_i - b_j), & b_i > b_j; \\ -k_{i,2}(v_i - b_j), & v_i \geq b_j \geq b_i; \\ 0, & b_j > v_i; \end{cases} \tag{2}$$

where $k_{i,1}$ is bidder i's winning regret parameter and $k_{i,2}$ is bidder i's losing regret parameter. Here we assume $k_{i,1}, k_{i,2} \in (0, C]$ where C is a positive real number. This assumption can be interpreted as follows: on one hand, empirical studies (Filiz-Ozbay & Ozbay, 2007; Engelbrecht-Wiggans & Katok, 2007, 2009) show that both winning regret and losing regret have effect on the bidder's evaluation; on the other hand, neither winning regret nor losing regret is so large that the direct profit can be ignored in the bidder's evaluation. The evaluation function (2) involves the following three cases. Case 1 is that bidder i wins the auction ($b_i > b_j$). In this case, the evaluation value is the gain $v_i - b_i$ offset by the weighted winning regret $k_{i,1}(b_i - b_j)$. Case 2 is for the situation $v_i \geq b_j \geq b_i$. In this case, the bidder i loses the auction but feels regretful because if he/she presents a little higher than b_j he/she could gain $v_i - b_j$ so that the evaluation value is $-k_{i,2}(v_i - b_j)$, it should be mentioned that we treat the tie case as lose here to reflect a relatively conservative attitude of an involved bidder; In Case 3, that is, $b_j > v_i$, bidder i loses the auction. However, there is neither regret nor gain for him/her.

For representing the relative position of the value, we introduce the satisfaction function which is a normalized evaluation function as follows:

$$u_i(b_i, b_j) = \frac{f_i(b_i, b_j) - LBf_i(b_i, b_j)}{UPf_i(b_i, b_j) - LBf_i(b_i, b_j)}, \tag{3}$$

where $LBf_i(b_i, b_j)$ and $UPf_i(b_i, b_j)$ are a lower bound and an upper bound of $f_i(b_i, b_j)$, respectively. Since $-Cv_i \leq f_i(b_i, b_j) \leq v_i$ always holds, we take v_i and $-Cv_i$ as the upper bound and lower bound of f_i, respectively, and rewrite (3) as follows:

$$u_i(b_i, b_j) = \begin{cases} ((v_i - b_i) - k_{i,1}(b_i - b_j) + Cv_i)/(1 + C)v_i, & b_i > b_j; \\ (-k_{i,2}(v_i - b_j) + Cv_i)/(1 + C)v_i, & v_i \geq b_j \geq b_i;. \\ C/(1 + C), & b_j > v_i; \end{cases} \tag{4}$$

We call $u_i(b_i, b_j)$ as the satisfaction level of b_j for b_i. For simplicity, we set

$$u_i^1(b_i, b_j) = ((v_i - b_i) - k_{i,1}(b_i - b_j) + Cv_i)/(1 + C)v_i, \tag{5}$$

$$u_i^2(b_j) = (-k_{i,2}(v_i - b_j) + Cv_i)/(1 + C)v_i. \tag{6}$$

We model the decision process of a conservative bidder in first-price sealed-bid auctions. Speaking in detail, for each available bidding price b_i, the bidder i conservatively contemplates a scenario b_j which brings him/her a relatively bad result with a relatively high probability. Mathematically, given b_i, b_j, which leads to a relatively bad result with a relatively high probability, can be obtained as the solution of the following bi-objective optimization problem

$$\max_{b_j} \pi_i(b_j), \ \min_{b_j} u_i(b_i, b_j). \tag{7}$$

We can find out one Pareto optimal solution of (7) from the set of all nondominated solutions as follows:

$$b_j(b_i) \in \arg\min_{b_j} \max\{1 - \pi_i(b_j), u_i(b_i, b_j)\}. \tag{8}$$

$b_j(b_i)$ is the focused scenario amongst all scenarios b_j when bidder i presents the bidding price b_i and is called the focus point of b_i.