Preferece Revelation in Multi-Attribute Bidding Procedures: An Experimental Analysis

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Abstract

In this paper, the authors report on a computer-based laboratory experiment investigating whether disclosing the buyer’s preferences in a multi-attribute reverse English auctions affects buyer’s utility, suppliers’ profits and efficiency. The results show that full revelation of the buyer’s preferences significantly increases allocational efficiency. Suppliers use the additional information in their bidding decisions and make weakly significantly more profits. However, the experimental evidence does not support the hypothesis that the buyer is better off when revealing her preferences. At least, the results indicate that the buyer is not exploited by suppliers.

1 Introduction

Strategic sourcing pertains to the procurement of direct inputs with a long-term and critical impact on a firm’s value chain [10]. Negotiations in strategic sourcing are typically based on calls for tenders, often performed by “requests for quotations” (RFQ). RFQ processes are characterized by negotiation on multiple attributes of an object (a tangible or intangible good or a right to a service) [1], e.g. “FirstEnergy put out a request for coal that required suppliers to bid based on BTUs, sulfur and ash content, moisture, and transportation” [11].

In an RFQ process, a corporate buyer announces the technical specification of the object, lists a number of negotiable attributes and invites suppliers to submit multidimensional bids on the negotiable attributes. Subsequently, the buyer evaluates the bids, ranks them according to her preference relation regarding the negotiable attributes of the object in question and awards the contract to a supplier who submitted the highest ranked bid. In such a process, evaluation of bids and winner selection are labor-intensive, time-consuming, and costly which is why procurement departments are seeking to (partially) automate these tasks [13].

Recent advances in information technology allow for the implementation of novel negotiation protocols enabling multi-lateral negotiations among a buyer and multiple suppliers. These electronic multi-attribute reverse (procurement) auctions provide means to automate bid submission, bid evaluation and winner selection. In a multi-attribute auction, the buyer specifies preference trade-offs among multiple negotiable attributes of an object by defining a scoring rule (utility function) based on her preference relation. The scoring rule is used to evaluate submitted bids and to designate the contract to the bidder providing the highest score to the buyer [5].

In practice, buyers are often not willing to reveal their preferences because of sensitivity or security issues. They fear that a bidder exploits information about their preferences and shifts gains from trade from the buyer to the supplier. However, how can a supplier identify which technical specification he should optimally deliver with respect to the buyer’s valuation function and his production costs if his insights in the buyer’s preferences are limited?

We study the performance of a multi-attribute reverse English auction in the cases of non-disclosure and full disclosure of buyer’s preferences and investigate whether a buyer profits or suffers from revealing her preferences. Section 2 summarizes related work on multi-attribute auctions. Section 3 introduces the microeconomic system underlying our experiment. Section 4 discusses the experiment set-up and Section 5 draws conclusions from the experimental evidence.

2 Related work

Multi-attribute auctions are an extension to standard auction theory, among others, e.g., multi-unit or combinatorial auctions [4]. In fact, McAfee and McMillan mention multi-
dimensional bidding in the context of government contracting in their often cited auction theory survey [14]. Multi-attribute auctions have been said to represent the “last frontier” [9] in the generalization of auction theory. Different approaches to auctioning over multiple characteristics of an object have been proposed. Related auction institutions have been termed multiple issue [22], multivariate [4], multicriteria [9], and multidimensional auctions [6, 7, 12].

Che discusses the design of optimal multidimensional auctions [7]. He investigates a two-dimensional (price and quality) procurement problem in a sealed-bid context assuming independent costs across suppliers. The buyer is assumed to know the probability distribution of the symmetric bidders’ cost parameters. Che generalizes the revenue equivalence theorem to the two-dimensional case and finds that it is optimal for the buyer to discriminate the quality dimension in relation to the buyer’s true preferences in a first- and a second-score auction. The model by Che has been criticized for lack of applicability in real procurement scenarios [1]. Branco generalizes Che’s model to correlated costs among suppliers [6]. He finds that a two-stage procedure consisting either of a first- or a second-score auction are optimal: In the first stage, a supplier is selected and in the second stage, the buyer bargains about the quality dimension. In contrast to the approaches by Branco, the presented experiment investigates a single-stage bidding procedure, which enables simultaneous negotiation on price and non-price attributes.

Only few economic experiments have been undertaken with multi-attribute auctions, e. g., by Bichler and Koppius. While the former does not investigate the issue of preference revelation [5], Koppius finds that revealing more information about the state of competition and the buyer’s preferences increases the allocational efficiency of multi-attribute auctions [12]. He investigates a sole sourcing scenario in which four suppliers compete in a computerized multi-round, open-cry auction. The bidding procedure is similar to the one deployed in this experiment, although the institution considered here is based on real-time bid submission instead of sequential bidding rounds.

Several recent research prototypes implement multi-attribute auctions [17]. Bichler et al. present an object-oriented framework for the implementation of multi-attribute auctions, which is deployed in “a large-scale procurement marketplace for the retail industry” [3]. Other prototypes apply multi-attribute auctions to multi-agent systems for autonomous negotiations among software agents [8, 18].

Multi-attribute bidding procedures have also gained recent interest by vendors and operators of electronic procurement solutions [2], e. g. FrictionlessCommerce [1], Perfect Commerce [16], and Moai [19]. Not all commercial implementations are purely based on multi-attribute auctions. For instance, Moai enables a buyer to switch from an auction protocol to one or more bilateral negotiations [17]. Practical applications of multi-attribute procurement auctions have been reported for contract programming, e. g. in [20, 21].

3 Microeconomic system

Our experiment implements a multi-attribute bidding scenario in which a single buyer (bid-taker, auctioneer) intends to acquire a single, indivisible object from exactly one of five potential suppliers (bidders), denoted by \( i \in I = \{1, \ldots, 5\} \). The bid-taker specifies the required characteristics of the object in question except for three negotiable attributes, namely the price \( p \) and two abstract qualitative, non-price attributes \( x \) and \( y \).

The buyer announces her intention to acquire the object and asks the suppliers to submit bids on the negotiable attributes of the object. Each of the two non-price attributes has six discrete, abstract quality levels, \( x \in X = \{1, \ldots, 6\} \) and \( y \in Y = \{1, \ldots, 6\} \). A technical specification \((x, y)\) of the object is a combination of quality levels of the two non-price attributes. The price \( p \in P = \{0, 1, 2, \ldots, 150\} \) is a nonnegative integer. A bid comprises a technical specification and a price, i. e. \( b = (x, y, p) \in X \times Y \times P \).

Specifically, the buyer perceives the discrete quality levels of each non-price attribute as measures of increasing quality. Other attributes held equal, she strictly prefers a higher quality over a lower quality in each non-price attribute. Thus, her valuation function \( v : X \times Y \rightarrow \mathbb{R} \) is monotonically increasing in both \( x \) and \( y \) with decreasing marginal value. Moreover, the buyer trades off price for quality. She demands a lower price for a lower quality and is willing to pay a higher price for a higher quality. Her utility function \( u \) is given by

\[
u(x, y, p) = v(x, y) - p.
\]

Each supplier is able to produce any technical specification in the set \( X \times Y \). A supplier’s production cost function \( c_i : X \times Y \rightarrow \mathbb{R} \), \( i \in I \) is monotonically increasing in both \( x \) and \( y \) with increasing marginal costs. His profit is given by the profit function

\[
u_i(x, y, p) = \begin{cases} 
p - c_i(x, y) & \text{if } i \text{ supplies the object} \\
0 & \text{otherwise} \end{cases}.
\]

In the experiment, we investigate a multi-attribute reverse English auction. At any point in time, the bid \( b^* \) which achieves the highest buyer’s utility is publicly announced as current high bid. If a bid \( b' \) is submitted which provides a higher utility to the buyer, i. e. \( u(b') > u(b^*) \), \( b' \) becomes the new high bid \((b^* := b')\). The auction ends if no new high bid had been received for 120 seconds and the bidder who
submits the last high bid is designated the contract of the buyer. He produces and delivers the object with the technical specification of the (his) last high bid and is paid the price of that bid by the bid-taker.

The seller selected by the bidding procedure to supply the object is denoted by \( i \) and the delivery price and the delivered technical specification by \( \hat{p} \) and \( (\hat{x}, \hat{y}) \), respectively. Thus, an outcome \( \hat{o} \) is denoted by a quadruple \( (i, \hat{x}, \hat{y}, \hat{p}) \), \( \hat{p} \in I \times X \times Y \times P \). The payoff of the winning bidder \( i \) is \( \hat{p} - c_i(\hat{x}, \hat{y}) \); the other bidders receive a zero payoff.

The efficiency of an auction is measured by the social welfare of the resulting outcome \( \hat{o} \). The social welfare \( w \) is defined as the sum of buyer’s and sellers’ surplus [16]:

\[
w(i, \hat{x}, \hat{y}) = v(\hat{x}, \hat{y}) - c_i(\hat{x}, \hat{y})
\]

Note that whether an outcome is efficient depends only on the technical specification \( (\hat{x}, \hat{y}) \) and the supplier \( i \), but not on the price \( \hat{p} \). An outcome \( \hat{o} \) is called efficient if and only if the selected supplier \( i \) and the delivered technical specification \( (\hat{x}, \hat{y}) \) maximize the social welfare, i.e., \( (i, \hat{x}, \hat{y}) \in \arg \max_{(i,x,y)} \{w(i,x,y)\} \).

The maximum achievable social welfare is denoted \( \bar{w} = \max_{(i,x,y)} \{w(i,x,y)\} \). Notice that in order to ensure comparability of results, the auction outcomes are standardized and the maximum achievable social welfare of a standardized outcome is set to \( w = 77.0 \).

4 Experiment

4.1 Experimental design

We analyze two treatments, \( T^N \) (non-disclosure) and \( T^F \) (full disclosure). In treatment \( T^N \), the buyer does not reveal her utility function \( u(x, y, p) \). Since her preference relation is not known by the suppliers, bidding is an explorative process. If a bidder turns in a bid that does not provide the buyer with a utility higher than the current high bid, the bid is rejected and an according message is sent to the respective bidder (but not to the other bidders). In the instructions, the bidders receive the following verbal information concerning the buyer’s preferences:

1. Given identical qualitative attributes, the buyer prefers the bid with the lower price.

2. The buyer prefers a higher quality level to a lower quality level within a qualitative attribute all other attributes being equal.

3. A lower quality level in one qualitative attribute can be compensated by a higher quality level in the other qualitative attribute.

4. Likewise is it possible to compensate a lower quality level by a lower price and vice versa.

5. However, you do not know the trade-offs of the buyer concerning the three attributes.

Contrary to \( T^N \), the buyer fully reveals her scoring rule \( u(x, y, p) \) in treatment \( T^F \) and bidders are prevented from submitting bids which do not provide the buyer with a utility score higher than the current high bid. In addition to the verbal information given in treatment \( T^F \), the bidders receive a printout of the buyer’s utility score for each technical specification. Accordingly, the bidder screen contains a decision support tool which the bidder may use to calculate the utility score of a triple \( (x, y, p) \).

Each treatment is investigated in eight experimental sessions. In each session, five subjects participate in six consecutive procurement auctions of the same treatment. Each of the five subjects takes on the role of a supplier and and is assigned a different sequence of six production cost schedules, so that there is a unique bidding equilibrium in each round. There is a unique bidding equilibrium in each auction. Throughout the experiment, the production costs remains private information to the respective supplier and a supplier is provided no information about the other suppliers’ production costs. The suppliers’ production cost schedules and the buyer’s valuation functions were randomized a priori and varied between auctions, but the sequence of cost schedules was kept identical across sessions in order to guarantee comparability of results. The number of competing suppliers and the number of consecutive auctions is public information. The suppliers also know that in each auction only one supplier is designated the contract by the buyer and that only this winning bidder makes a profit or loss. The subjects remain anonymous during an experimental session. Communication among subjects is not permitted other than through bidding. The history of winning bids is available to all bidders but the identity of the winning or any other bidder is not revealed. Both treatments are conducted with the same experiment software except for the necessary differences in the bidder clients. The buyer was not physically present during a session, but built into the experiment software.

4.2 Conducting the experiment

The experiment was conducted at the experimental laboratory of the Institute of Information Management and Systems, University of Karlsruhe. Subjects were drawn randomly from a large pool of student volunteers. None of the subjects had ever participated in a procurement experiment before and none of the subjects participated repeatedly. Upon arrival at the laboratory, subjects were randomly
seated at a visually isolated computer terminal. Sixteen ses-
sions were conducted in which 80 different subjects partic-
ipated.

The subjects received written instructions which were
also read aloud by a research assistant. Before the experi-
ment started, each subject had to answer an extensive ques-
tionnaire about the rules of the auctions and the experiment.
Communication between participants was not permitted. At
the end of an experimental session, the subjects were paid
in cash according to their final account balance. The equi-
librium payoffs range from 3.3 to 4.7 euros per auction. A
bidder’s payoff is credited to his experiment account in ad-
dition to a show-up fee of 10 euros. The average earning of
a subject was 13.3 euros. The sessions lasted for 95 min-
utes on average including oral instructions and answering
the questionnaire.

4.3 Results

Table 1 reports the mean values of the standardized vari-
ables for social welfare, buyer’s, and suppliers’ surplus for
each session in both treatments. The experimental results
show that, on average, both, the buyer’s utility and suppli-
ers’ profit are larger in treatment $T^F$ than in $T^N$, but
the data is inconclusive. The buyer’s utility in treatment $T^N$
is equal to or higher than that in treatment $T^F$ in four ses-
sions and in three sessions, the suppliers’ profit in treatment $T^N$
is equal to or larger than that in $T^F$. The increase in suppli-
ners’ surplus is weakly significant (Mann-Whitney $U$-test or
MWU for short, 2-tailed: $N = 16, U = 14.5, p = .0701$),
but the buyer does not significantly profit from revealing her
preferences (MWU, 2-tailed: $N = 16, U = 24, p = .4410$).

Allocational efficiency, measured by the realized social wel-
fare, is clearly closer to the maximum in treatment $T^F$ than
in treatment $T^N$. The increase in social welfare is highly
significant (MWU, 1-tailed: $N = 16, U = 5, p = .0012$).

5 Conclusions

We observe that the revelation of the buyer’s preferences
significantly increases allocational efficiency. The experi-
ment shows that the bidders successfully use the additional
information about the buyer’s preferences in their bidding
decisions. They are more often able to identify technical
specifications that are optimal with respect to the buyer’s
valuation and the suppliers’ cost of production. As a result,
suppliers make weakly significantly more profits.

We do not observe that revelation of the buyer’s prefer-
ences increases her utility, but we do also not find that sup-
pliers shift gains from trade from the buyer to the sellers,
i.e. preference revelation creates real value. Therefore, the
buyers’ fear of becoming exploited seems unfounded. Yet,
significance of that result is weak and it is not appropriate
to conclude from the experimental results alone that a buyer
is better-off when revealing her preferences.

Still, we recommend buyers in procurement auctions for
objects with several negotiable attributes to seriously re-
consider reluctant policies regarding preference revelation.
Note that the number of bidders in the experiment had been
fixed in advance. This does not hold in most practical ap-
lications. Moreover, participating in a B2B procurement
auction is not free of costs. There are (explicit or implicit)
transaction costs that have not been modelled in the exper-
iment. A “real” bidder will carefully compare the partic-
ipation costs with the expected gains from bidding in the
auction. If expected suppliers’ surplus is high—as it is in

<table>
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<th>Session</th>
<th>$u(\hat{i}, \hat{x}, \hat{y})$</th>
<th>$u_i(\hat{i}, \hat{x}, \hat{y})$</th>
<th>$w(\hat{i}, \hat{x}, \hat{y})$</th>
<th>$u(\hat{i}, \hat{x}, \hat{y})$</th>
<th>$u_i(\hat{i}, \hat{x}, \hat{y})$</th>
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| Mean    | 73.18           | 3.35            | 76.53           | 72.62           | 2.52            | 75.14           |
| Std Dev | 0.96            | 1.12            | 0.65            | 0.73            | 0.60            | 0.47            |

Note: $T^F$: Full disclosure of buyer’s preferences. $T^N$: Non-disclosure of buyer’s preferences. $u(\hat{i}, \hat{x}, \hat{y})$: Buyer’s utility. $u_i(\hat{i}, \hat{x}, \hat{y})$: Suppliers’ profit. $w(\hat{i}, \hat{x}, \hat{y})$: Social welfare. Maximum of standardized social welfare: $\bar{\bar{w}}(\hat{i}, \hat{x}, \hat{y}) = 77.0$. Values averaged over last four rounds of each session.
treatment $T^F$ with full preference revelation—an auction is far more attractive for participation than an auction with low bidder surplus like treatment $T^N$. Thus, one can expect more suppliers to bid in the $T^F$ auction. It is a well-known result that the auctioneer’s surplus increases with the number of bidders due to the increased level of competition [15]. The effect of preference revelation on the number of participating bidders is therefore an interesting question for future research.

Acknowledgement

We are grateful to Christof Weinhardt, Martin Bichler, and Karl-Martin Ehrhart for many helpful discussions. Financial support by the Institute of Information Management and Systems is gratefully acknowledged. We thank IBM Research Zürich for their sponsorship of the experimental laboratory. This research has been partially conducted under a grant from the Social Sciences and Humanities Research Council Canada.

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