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PREFERENCE REVELATION IN MULTI-ATTRIBUTE REVERSE ENGLISH AUCTIONS: A LABORATORY STUDY

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Abstract

The effects of preference revelation on allocational and Pareto efficiency are studied in a multi-attribute reverse English auction. Multi-attribute reverse auctions have been proposed as market institutions for electronic request for quotation buying processes. Preference revelation is a crucial question in multi-attribute reverse auctions in terms of the efficiency of auction outcomes. Results from a computer-based laboratory experiment are reported and auction outcomes are analyzed regarding the buyer's and suppliers' surplus, efficiency, and Pareto efficiency. The results show that suppliers make more profits when preferences are revealed, but not at the expense of the buyer, and that full revelation of the buyer's preferences significantly increases allocational and Pareto efficiency.

Keywords: Multi-attribute auction, preference revelation, electronic sourcing, request for quotation, economic experiment, electronic negotiation

Introduction

The sourcing of differentiated, high-valued goods and services (henceforth, objects) with a critical impact on a firm's value chain regularly requires corporate buyers to negotiate on multiple attributes of an object, e.g., quality of service, lead time, terms of transportation, or warranty, in addition to its price. Negotiations in strategic sourcing are therefore based on calls for tenders, often performed by *requests for quotations* (RFQ). In an RFQ process, a corporate buyer announces the technical specification of the object in question, lists a number of negotiable attributes, and invites potential suppliers to submit multidimensional bids on the negotiable attributes. Subsequently, the buyer evaluates the submitted bids (offers), ranks them according to her preference relation regarding the negotiable attributes, and awards the contract to the supplier who submitted the highest ranked bid. For instance, a regional utility published a "request for coal that required suppliers to bid based on BTUs, sulfur and ash content, moisture, and transportation" (Kafka et al. 2000) and was willing to negotiate on different qualitative attributes of coal described by its heating value, contamination, and liquid content. Underlying this multi-criteria decision-making process is the rationale that the buyer seeks to designate the contract to the supplier who offers the best price/performance ratio and not necessarily to the supplier who offers the lowest price, since often the lowest cost seller does not provide the best combination of price and quality (Shachat and Swarthout 2002). On the other hand, the corporate buyer assumes that (1) the procured object varies in the non-price attributes, i.e., in quality (object heterogeneity), and (2) that suppliers have different comparative cost advantages when producing the object (bidder heterogeneity). These buying processes apply to a diverse spectrum of goods and services, e.g., the sourcing of contract programming (Snir 2000) or truck fleets (Kafka et al. 2000).

In an RFQ-based buying process, bid evaluation and winner selection are labor-intensive, time-consuming, and costly, which is why procurement departments are seeking to (partially) automate the RFQ process (Beil and Wein 2002). However, negotiations

in electronic sourcing are commonly based on reverse auctions in which the price is the unique strategic dimension and all non-price attributes of an object are fixed prior to the negotiation (price auctions). Although price auctions lead to increased procurement performance with standardized objects, they potentially lead to inefficient outcomes when differences in quality exist and suppliers possess comparative cost advantages along quality dimensions (Koppius 2002).

Recent advances in information and communication technology facilitate the implementation of electronic auctions, which closely resemble the RFQ buying process. These multi-attribute auctions provide the means to automate bid submission, bid evaluation, and winner selection in terms of an *electronic* request for quotation (eRFQ). In a multi-attribute reverse auction, the buyer (bid-taker, auctioneer) specifies her value trade-offs among multiple negotiable attributes of an object by defining a scoring rule (utility function) based on her preference relation. During the auction process, the buyer solicits bids from invited suppliers (bidders) according to the rules of the bidding procedure. The buyer's scoring rule is used to evaluate submitted bids and to designate the contract to the bidder providing the highest utility score to the buyer.

In the present experiment, the principle of a standard English auction is adapted to the multi-attribute case and applied to a sole sourcing scenario. The buyer faces the crucial question of whether or not to reveal the scoring rule to guide the suppliers through the bidding process. In practice, buyers are often not willing to reveal their preferences, because of fear that a bidder will exploit information about their preferences and shift gains from trade from the buyer to the supplier. However, if guidance by a scoring rule is missing, the cognitive efforts for suppliers to identify an efficient bid are multiplied. It seems, therefore, unlikely that an unguided multi-attribute reverse English auction leads to an efficient outcome.

This paper reports on the results of a computer-based laboratory experiment designed to compare the performance of a multi-attribute reverse English auction in the cases of non-disclosure and full disclosure of the buyer's preferences. The next section relates the experiment to existing literature. The experimental design as well as the theoretical framework underlying the experiment and the research hypothesis are introduced in the third section. The fourth section analyses the data and presents the experimental results. The final section summarizes the main findings.

Related Work

Multi-attribute auctions represent an extension to standard auction theory (McAfee and McMillan 1987, p. 732), among others, e.g., multiunit or combinatorial auctions (Krishna 2002). The term *multi-attribute auction* comprises a number of related, but distinctly different, approaches to auctioning over multiple characteristics of an object. Related auction institutions have been termed multiple issue (Teich et al. 1999), multicriteria (De Smet 2003), and multidimensional auctions (Branco 1997; Che 1993; Koppius 2002). A basic distinction exists between multi-attribute auctions based on a scoring function and those without any explicit scoring rule. One approach of the latter category is the leap-frog method in which the bid-taker remains passive and each bid must be an improvement over the previous bid in at least one of the attributes and at the same time not worse in any other attribute (Teich et al. 1999). The class of multi-attribute auctions considered in this paper is based on an explicit model of the buyer's preferences in form of a scoring rule.

Generalizations of standard auction theory to the multi-attribute case have been discussed by Thiel (1988), Che (1993), Branco (1997), and more recently by David et al. (2002) and De Smet (2003). Thiel shows that the design of multidimensional auctions is equivalent to the design of standard single dimensional auctions, assuming that the buyer has a fixed budget and does not value any price reduction. The latter assumption in general does not hold in the corporate procurement context considered here. Che discusses the design of optimal multidimensional auctions and investigates a two-dimensional (price and quality) procurement problem with sealed-bid auctions assuming independent costs across bidders. Branco extends the analysis to correlated costs among suppliers and investigates the design of efficient multidimensional auctions. In contrast to Che and Branco, the present experiment investigates an adaptation of the principle of an open-cry, ascending, i.e., English, auction to the multi-attribute case.

David et al. study a multi-round variant of a multi-attribute reverse English auction in which the buyer publicly announces the scoring rule and suppliers bid sequentially in a randomly defined order. The buyer's and suppliers' preferences are modeled using *multi-attribute utility theory* (MAUT) (Keeney and Raiffa 1976). The suppliers' costs are independently and identically distributed and the distribution function is known by the buyer. David et al. show that rational bidders first choose the Pareto optimal non-price attributes with respect to the scoring rule independent of the current high bid and then choose a price with respect to the desired utility score given the levels for the non-price attributes. This holds in a model of supplier types with a single cost parameter and is extended to cases when supplier types possess two or more cost parameters. Although MAUT is

widely used to model decision-maker's preferences (Clemen 1996) and has been used in multi-attribute auctions (Bichler 2000), the preference model underlying this experiment is based on a stylized quasi-linear utility function introduced by Milgrom (2000). De Smet criticizes (1) the assumption of total comparability among bids and (2) the need to *a priori* determine weights in MAUT-based institutions. His approach does not require total comparability between multi-criteria alternatives (Vincke 1996). De Smet models an English auction that accepts incomparabilities among bids by restricting comparisons to "similar" bids and allows for updates of weights during the bidding procedure. Yet, the proposed model compromises on the uniqueness of the final outcome and on other properties of game-theoretic auction models. Only a few experimental investigations have been undertaken with multi-attribute auctions, e.g., by Bichler (2000) and Koppius (2002). While Bichler does not investigate the issue of preference revelation, Koppius finds that revealing more information about the state of competition and the buyer's preferences increases the allocational efficiency of multi-attribute auctions. He investigates a sole sourcing scenario in which four suppliers compete in a computerized multi-round auction. In contrast to the multi-round variants in Koppius and in David et al., the institution considered here is based on real-time bid submission instead of sequential bidding rounds.

Experiment

Microeconomic System

The laboratory experiment implements a multi-attribute bidding scenario in which a single buyer intends to acquire a single, indivisible object from exactly one of five potential suppliers $i \in I = \{1, \dots, 5\}$. 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 each of the five suppliers to submit bids on the negotiable attributes of the object. She provides the suppliers with a description of the negotiable attributes and of the rules of a microeconomic institution. Each of the two non-price attributes has six discrete, abstract quality levels, denoted $x \in X = \{1, \dots, 6\}$, $X \cap \mathbb{Z}$ and $y \in Y = \{1, \dots, 6\}$, $Y \cap \mathbb{Z}$. A technical specification (x, y) , $x \in X$, $y \in Y$ of the object is a combination of quality levels of the two non-price attributes. The price p is a nonnegative integer in the interval $P = [0; 150]$: $p \in P \cap \mathbb{Z}$.

Specifically, the buyer perceives the discrete quality levels of each non-price attribute as a measure of increasing quality. Other attributes held equal, she strictly prefers a higher quality to 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 . 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. In the experiment, her scoring rule u is monotonically increasing with decreasing marginal utility and is given by

$$u(x, u, p) = v(x, y) - p \tag{1}$$

Five suppliers $i \in I$ participate in an auction. Each supplier is able to produce any technical specification in the set $X \times Y$. A supplier i '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

$$u_i(x, y, p) = \begin{cases} p - c_i(x, y), & \text{if } i \text{ supplies the object} \\ 0 & , \text{otherwise} \end{cases} \tag{2}$$

In the experiment, a multi-attribute reverse English auction is investigated (Bichler et al. 1999). The institution constitutes an iterative bidding procedure in which each bidder is eligible to submit multiple subsequent bids. A bid b comprises a technical specification and a price, i.e., $b = (x, y, p)$, $x \in X$, $y \in Y$ and $p \in P$. Each submitted bid b is evaluated by the buyer with respect to her utility function u . 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 is received for 120 seconds. The bidder i 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 transaction price and the delivered technical specifications are denoted by \hat{p} and (\hat{x}, \hat{y}) respectively. The payoff of the winning bidder i is $\hat{p} - c_i(\hat{x}, \hat{y})$. The other bidders do not produce and sell and thus make no profits (sole sourcing scenario). Note that the institution constitutes a reverse auction, because a single buyer solicits bids from multiple suppliers. It is nonetheless an ascending auction, since the bids gradually increase the buyer's utility.

Experimental Design

The experiment investigates two treatments, *TN* (non-disclosure) and *TF* (full disclosure). In treatment *TN*, the buyer does not fully reveal her utility function $u(x, y, p)$. In the instructions, the bidders receive the following information (monotony constraints) about 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.*

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

If a bidder turns in a bid that does not provide the buyer with a utility score higher than the current best bid, the bid is rejected and an appropriate message is sent to the respective bidder (but not to any other bidder). Figure 1 shows the bidding screen in treatment *TN*. The right-hand panel contains the bid submission interface. The bidder selects a quality level for each qualitative attribute from the drop-down lists and enters a price. The software automatically calculates the production costs given the three attributes and the potential profit in case this bid is awarded the contract of the buyer. If the data entered in the bid submission interface is valid, the submission button becomes active and the bidder is able to submit his bid.

Contrary to *TN*, in treatment *TF*, the buyer reveals her scoring rule $u(x, y, p)$ and bidders are prevented from submitting bids that do not provide the buyer with a utility score higher than the current high bid. In addition to the verbal information given in treatment *TN*, the bidders receive a printout of the buyer’s valuation for each technical specification and a printout of the buyer’s utility score for each technical specification in a price range between 41 and 150. Accordingly, the bidding screen in treatment *TF* contains a decision support tool, which the bidder may use to calculate the utility score of a triple $u(x, y, p)$. The left-hand panel shown in Figure 2 allows bidders to perform the calculation. If the calculation results in a valid bid, i.e., the calculated utility score is higher than the score of current best bid, the transfer button becomes active and the bidder is able to transfer the current triple to the bid submission interface in the right-hand panel. The functionality of the bid submission interface is analogous to treatment *TN*. In both treatments, the current best bid as well as the remaining time for bid submission is permanently shown to the bidder in the panel labeled “Current high bid” (see Figures 1 and 2). The clock in the upper right corner counts down to zero and is reset to two minutes whenever a new high bid is received.

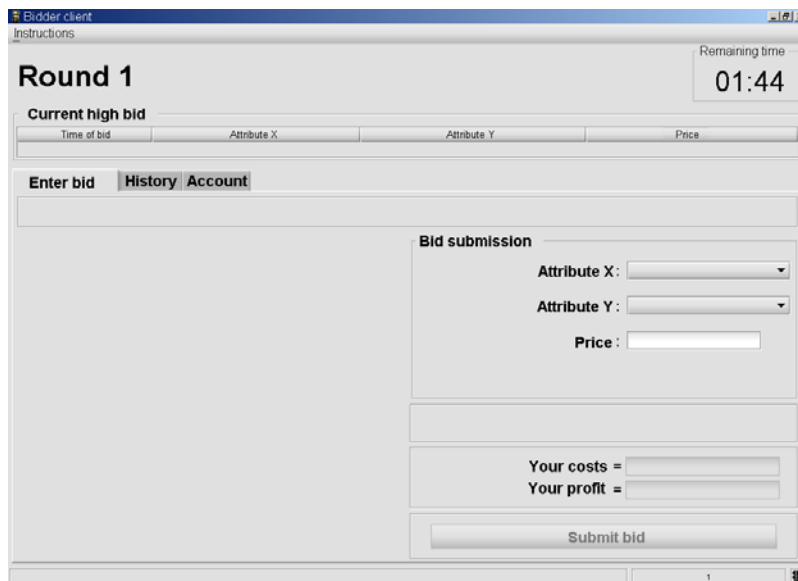


Figure 1. Bidder Client in Treatment *TN*

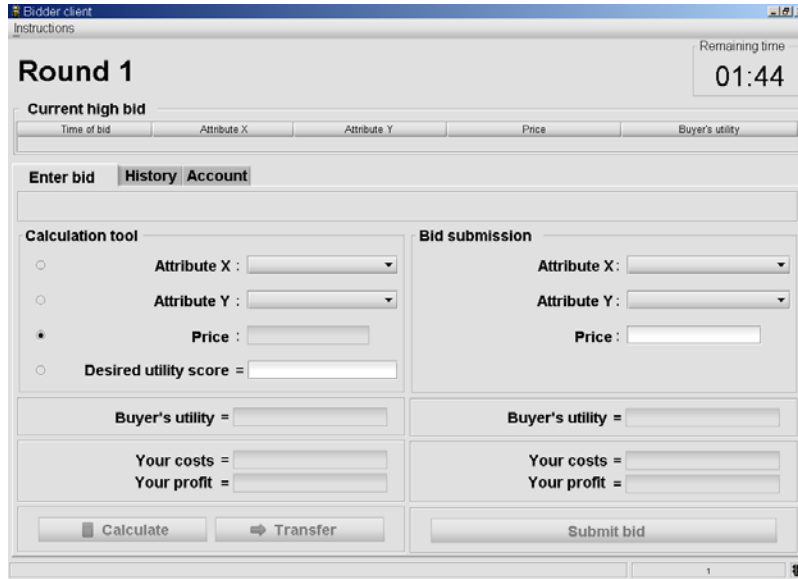


Figure 2. Bidder Client in Treatment TF

Each treatment is investigated in eight experimental sessions. In every session, five experimental subjects participate in six consecutive reverse auctions (rounds) of the *same* treatment. Each of the five subjects takes on the role of a supplier. In each of the six consecutive rounds within a session, the buyer has a different valuation for technical specifications and each supplier is assigned a different production cost schedule.

The suppliers' production cost schedules and 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 ensure comparability of results. Note that in each of the six rounds, a unique bidding equilibrium exists.

Throughout the experiment, the production cost schedules remain private information to the respective supplier and a supplier is provided no information about the other suppliers' production costs. The number of competing suppliers and the number of consecutive auctions are public information. The bidders 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.

At the beginning of a session, each subject is credited a show-up fee of 10 experimental currency units (ECU) to his experiment account. In each of the six consecutive auctions, the payoff of the winning bidder is charged to his experiment account: A loss is deducted from his balance, while a profit is credited to his account. The equilibrium payoff of the winning bidder ranges from 3.3 to 4.7 ECU depending on the round. Throughout the experiment, subjects have access to their current payoff (account balance). At the end of a session, the account balance is converted to Euro, where one ECU equals one Euro. In case a subject's account balance is negative, the subject is paid a zero payoff. Both treatments are conducted with the same experiment software, except for the necessary adjustments in the bidding screen.

Performance Measures

The supplier selected by the institution to supply the object is denoted by i (see above) and the transaction price and the delivered technical specification are denoted by \hat{p} and (\hat{x}, \hat{y}) , respectively (see above). Hence, an outcome (deal) δ is denoted by $\delta = (i, \hat{x}, \hat{y}, \hat{p})$, $i \in I$, $\hat{x} \in X$, $\hat{y} \in Y$, and $\hat{p} \in P$. The social welfare w of an outcome δ is defined as the sum of buyer's and the selected suppliers' surplus (Milgrom 2000), i.e.,

$$\begin{aligned}
 w(\hat{o}) &= w(\hat{i}, \hat{x}, \hat{y}, \hat{p}) \\
 &= u(\hat{x}, \hat{y}, \hat{p}) + \sum_{i=1}^5 u_i(\hat{x}, \hat{y}, \hat{p})
 \end{aligned}
 \tag{3}$$

It follows from Equations (1) and (2) that

$$w(\hat{o}) = v(\hat{x}, \hat{y}) - c_i(\hat{x}, \hat{y}).
 \tag{4}$$

Note that the social welfare depends only on the selected supplier and delivered technical specification, but not on the price, i.e., $w(i, x, y, p) = w(i, x, y)$. In order to ensure comparability of results, the auction outcomes are standardized. The maximum achievable social welfare (global optimum) of the standardized outcome is denoted $\bar{w}(\bar{i}, \bar{x}, \bar{y})$.

The performance of an auction is measured by the allocational and Pareto efficiency of an auction outcome \hat{o} . An outcome \hat{o} is called (allocational) *efficient* if and only if there is no other deal that leads to a higher social welfare, i.e., $\exists (i', x', y') : v(x', y') - c_{i'}(x', y') > v(\hat{x}, \hat{y}) - c_i(\hat{x}, \hat{y})$ (Milgrom 2000). Allocational efficiency is measured in terms of deviations of actual outcomes (final allocations) from maximum achievable social welfare, with misallocations representing larger *foregone gains (FG)* from trade weighted more heavily (Friedman 1993). The measure FG is defined as the unrealized social welfare as a percentage of potential maximum social welfare in a given auction, i.e., $FG = (\bar{w}(\bar{i}, \bar{x}, \bar{y}) - w(\hat{i}, \hat{x}, \hat{y})) / \bar{w}(\bar{i}, \bar{x}, \bar{y})$. Larger values of FG indicate larger foregone gains from trade and thus less efficient outcomes. Similarly, the *relative efficiency (RE)* of an outcome is defined as the actual achieved social welfare as a percentage of the potential maximum social welfare, i.e., $RE = w(\hat{i}, \hat{x}, \hat{y}) / \bar{w}(\bar{i}, \bar{x}, \bar{y}) = 1 - FG$. Larger values of RE indicate a higher efficiency.

The division of the social welfare between the buyer and the winning supplier is measured in terms of deviations of actual buyer's and winning suppliers' surplus from the maximum achievable social welfare. The measure *BU* is defined as the *buyer's surplus* as a percentage of the maximum social welfare in a given auction $BU = u(\hat{x}, \hat{y}, \hat{p}) / \bar{w}(\bar{i}, \bar{x}, \bar{y})$ and the measure *SP* is defined as the *winning suppliers' surplus* as a percentage of the maximum social welfare in a given auction $SP = u_i(\hat{x}, \hat{y}, \hat{p}) / \bar{w}(\bar{i}, \bar{x}, \bar{y}) = 1 - BU$. Larger values of BU and SP indicate larger shares by the buyer and winning supplier, respectively.

An outcome \hat{o} is called *Pareto efficient* if and only if there is no other technical specification with which the selected supplier i could induce a higher social welfare (Pareto efficiency of the deal), i.e., $\exists (x', y') : w(i, x', y') > w(i, \hat{x}, \hat{y})$. Note that the Pareto efficient technical specification $(x', y')_i$ is unique for each supplier $i \in I$. Whether an outcome is Pareto efficient depends on the technical specification (\hat{x}, \hat{y}) , but not the transaction price \hat{p} . In case of Pareto inefficient outcomes, the number of Pareto-improving bids is employed as a measure, following Koppius (2002). NPareto denotes the number of *weakly* Pareto-improving bids, i.e., the number of bids that provide the buyer with a utility at least as high as the utility of the actual winning bid and at the same time provide the winning supplier with a profit at least as high as the profit of the actual winning bid. NParPlus denotes the number of *strictly* Pareto-improving bids, i.e., the number of bids that provide the buyer with a utility higher than the utility of the actual winning bid and at the same time provide the winning supplier with a profit higher than the profit of the actual winning bid. In other words, given a winning bid, NPareto counts the number of bids the winning supplier i could have submitted that put the buyer and the winning supplier on par with the winning bid or make either the buyer or the winning supplier better off without hurting the other trading partner. NParPlus aggravates the conditions and demands that the counted bids make both parties strictly better off. In order to investigate whether group or individual idiosyncrasies account for the Pareto efficient outcomes, the individual and group performance are computed. An individual bidder's relative performance is given by the percentage of the number of rounds in which a bidder submits a Pareto efficient bid in relation to the maximum number of rounds. Individual bidders are grouped by identical sequences of production cost schedules. Groups are denoted by Roman digits (I-V). The group performance is given by the number of Pareto efficient bids submitted by a group of subjects during a session in relation to the maximum number of winning bids. When counting Pareto efficient bids in treatment *TN*, it is sufficient that a Pareto efficient bid is submitted by a supplier, but it is not required that the bid is accepted by the buyer.

Theoretical Framework and Research Hypothesis

Underlying this experiment is the assumption of the private values model, i.e., each bidder knows his production costs with certainty, but has no information about other bidders' valuations. Contrary to the literature on the *independent* private values model (e.g., McAfee and McMillan 1987), bidders do *not* know the distribution from which the other bidders' valuations are drawn. In the present experiment, the principle of a standard English auction is adapted to the multi-attribute case. Bidders have a dominant bidding strategy in both treatments (e.g., McAfee and McMillan 1987), i.e., the lack of knowledge about the distribution of valuations does not affect the bidding strategy in either of the two treatments.

In the chosen adaptation, the buyer is required to lay down a scoring rule based on her preference relation. It is assumed that the scoring function coincides with the buyer's true preferences and thus corresponds to her utility function. The issues of preference elicitation and misrepresentation of preferences are not subject to the present experiment (Beil and Wein 2002; Bichler 2000). A crucial question for the buyer is whether or not to reveal the scoring rule to guide the bidders through the bidding process. Assuming rational bidders, efficient outcomes are expected independent of the buyer's decision, but with very different implementations of the dominant bidding strategy. In case the buyer does reveal her preferences, rational bidders are expected to calculate and submit an efficient bid resulting in efficient auction outcomes. In case the buyer does not fully reveal her preferences, the suppliers face a dilemma: How shall they identify and submit an efficient bid, if they do not know the buyer's scoring rule prior to the auction? If the negotiable attributes are discrete as in the present experiment, it is possible to completely enumerate profitable bids and bid in the order of decreasing profits. However, a complete enumeration is not feasible in many practical applications, because the informational and computational demands quickly ask too much of bidders. For instance, the complete enumeration of feasible bids in the present experiment results in $5,400 = X \times Y \times P$ combinations. It seems, therefore, likely that bidders choose an ad hoc bidding strategy in which they explore the attribute space by bidding different technical specifications at gradually decreasing prices in a trial-and-error manner. This pragmatic approach is unlikely to achieve identical (Pareto) efficient outcomes compared to the case of full preference revelation. This experiment is, therefore, based on the research hypothesis that non-disclosure of the buyer's preferences leads, in practical applications, to a lower efficiency and Pareto efficiency of auction outcomes and to differences in buyer's and suppliers' surplus.

Conducting the Experiment

The experiment was conducted at the experimental laboratory of the Chair for Information Management and Systems at the Universitaet Karlsruhe, Germany, and was carried out in German (labels in the bidding screens shown are translated). Subjects were randomly drawn from a large pool of student volunteers. The subjects were undergraduate and graduate students from different disciplines with a majority from the Department of Economics and Business Engineering. Concerning the transferability of experimental results to business environments, Plott (1982, p. 1520) reports that no subject pool differences have been reported between "real" businessmen and student subjects. In a laboratory experiment, Dyer et al. (1989) compare student subjects with business executives and find "qualitatively similar" (Roth 1995) results. The general scepticism about transferability of experimental results to naturally occurring markets is contradicted by Plott and others with the argument that, if a theoretical prediction fails in a simplifying experiment, then there is little reason to expect it to occur in a more complicated field setting (see also the "parallelism precept" in Smith 1982, p. 936).

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 sessions were conducted in which 80 different subjects participated. The subjects received written instructions, which were also read aloud by a research assistant. At the beginning of each auction, the subjects received a printout of their individual production cost schedule. In treatment *TF*, the subjects were additionally provided with two printouts of the buyer's valuation and utility score. Before the session started, each subject had to answer an extensive questionnaire about the rules of the auctions and the experiment. At the end of an experimental session, the subjects were paid privately in cash according to their final account balance. A bidder's payoff is credited to his experiment account in addition to the show-up fee of 10 Euro. The average earning of a subject was 13.3 Euro including the show-up fee. Overall, a session lasted for an average of 95 minutes including reading the instructions and answering the questionnaire. The average hourly earning of a subject was therefore 8.4 Euro/hour, which approximately corresponds to the average salary of students at German academic institutions.

Experimental Results

In this section, a statistical analysis comparing the bids from the sessions in the two treatments is presented. The treatments are compared by distribution-free tests. For each test, a significance level of 5 percent (strong significance) or 10 percent (weak significance) is required.

The inferential analysis is based on the standardized outcomes of the *last four* auction rounds in each independently conducted session. The first two of the six consecutive auctions are considered as trial rounds. The subjects did *not* know about this differentiation and a monetary reward was offered in all six rounds of a session.

To illustrate the market efficiency, Figure 3 compares the actual realized social welfare in both treatments with the maximum achievable social welfare. With one exception (session 2), the average social welfare is higher in treatment *TF* than in treatment *TN* and there is not a single session in which treatment *TN* yields a higher efficiency. Allocational inefficiencies, measured by unrealized gains from trade, were usually below 1 percent in treatment *TF*. In contrast, 2.4 percent of the potential social welfare was on average not realized in treatment *TN*. Table 1 shows that 27 or 84.4 percent of the 32 outcomes in treatment *TF* and 11 or 34.4 percent of the 32 outcomes in treatment *TN* were efficient. The difference between the two treatments with respect to efficiency is highly significant (Mann-Whitney U-test, or MWU for short, 1-tailed: $N = 16, U = 5, p < .01$).

Despite the lack of information about the buyer’s preferences, a fair number of efficient outcomes are observed in treatment *TN*. As the right-hand panel in Table 1 reports, there is at least one efficient outcome in every session, and in three sessions, two efficient outcomes are observed. This result indicates that the information provided to the subjects (instructions, printouts, information feedback about current and former high bids) and the user interface of the bidding screen were sufficient to achieve efficient outcomes in treatment *TN*.

Observation 1

In a multi-attribute English auction, efficiency is higher if the buyer’s preferences are known by the suppliers prior to the auction. If preferences are revealed, the average efficiency is close to the theoretical maximum. Independent of the preference revelation, efficiency is quite high in both treatments (above 95 percent of the maximum achievable social welfare).

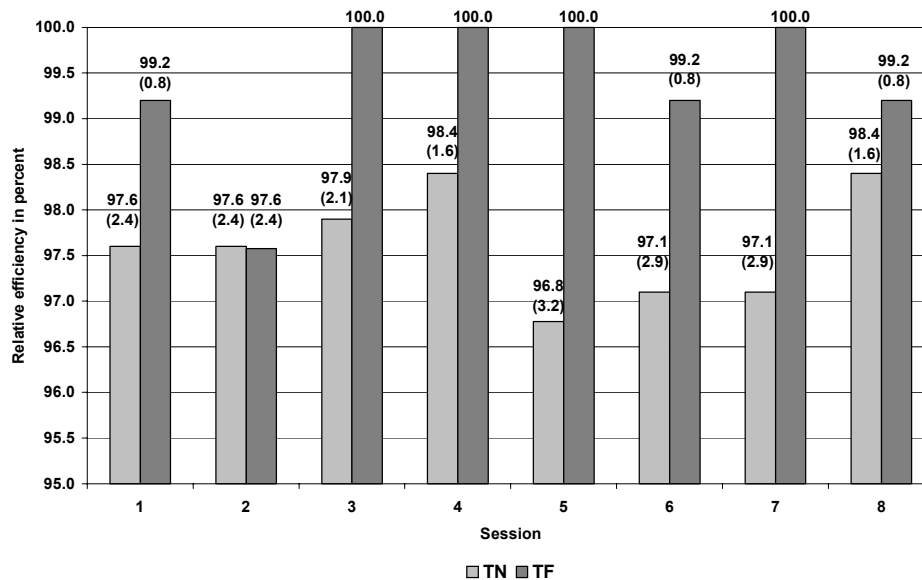


Figure 3. Relative Efficiency (RE) and Foregone Gains from Trade (FG is shown in brackets)

Table 1. Efficiency and Pareto Efficiency

Session	TF					TN			
	N	N ₁	N ₂	N ₃	N ₄	N ₁	N ₂	N ₃	N ₄
1	4	3	3	3	3	1	1	9	7
2	4	2	2	19	17	1	1	10	8
3	4	4	4	0	0	2	3	2	2
4	4	4	4	0	0	2	2	8	6
5	4	4	4	0	0	1	1	22	20
6	4	3	3	3	3	1	2	5	5
7	4	4	4	0	0	1	2	4	4
8	4	3	3	3	3	2	2	6	6
Total	32	27	27	28	26	11	14	66	58
Median		3.5	3.5	1.5	1.5	1.0	2.0	7.0	6.0
Mean \bar{x}		3.38	3.38	3.50	3.25	1.38	1.75	8.25	7.25
Std dev s		.74	.74	6.44	5.75	.52	.71	6.16	5.47

Note: N: Number of auction outcomes. N₁: Number of efficient outcomes. N₂: Number of Pareto efficient outcomes. N₃: Sum of NPareto. N₄: Sum of NParPlus.

Figures 4 and 5 compare the buyer’s utility and bidders’ profits. The data suggests that both the buyer’s utility and suppliers’ profit are larger in treatment TF than in TN. However, the illustrations are inconclusive. The buyer’s utility in treatment TN is equal to or higher than that in treatment TF in four sessions, but the differences are small (see Figure 4). However, treatment TF yields a higher utility for the buyer in the remaining four sessions and the differences are more clearly observable. The buyer’s utility is on average slightly higher in treatment TF than in TN, but the difference is not significant (MWU, 2-tailed: N = 16, U = 24, p = .4401).

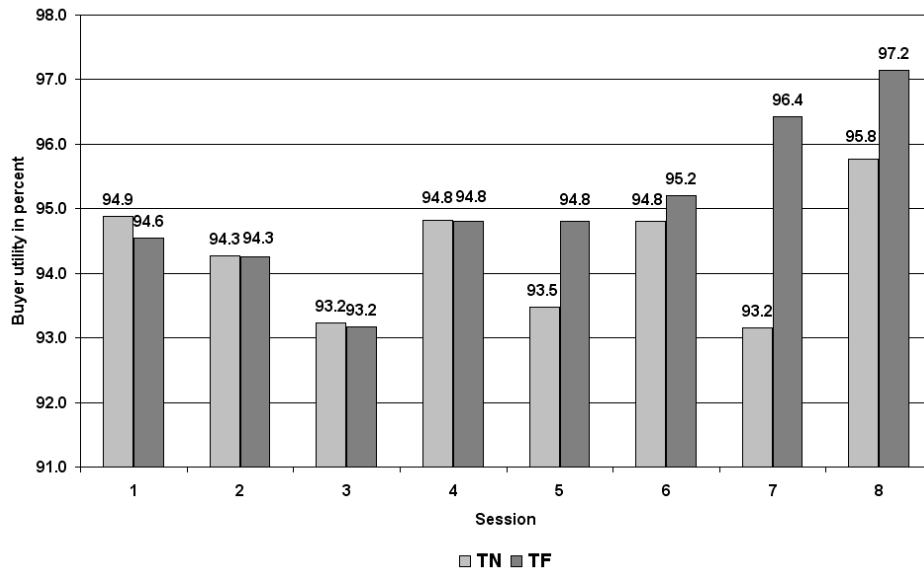


Figure 4. Buyer’s Utility (BU)

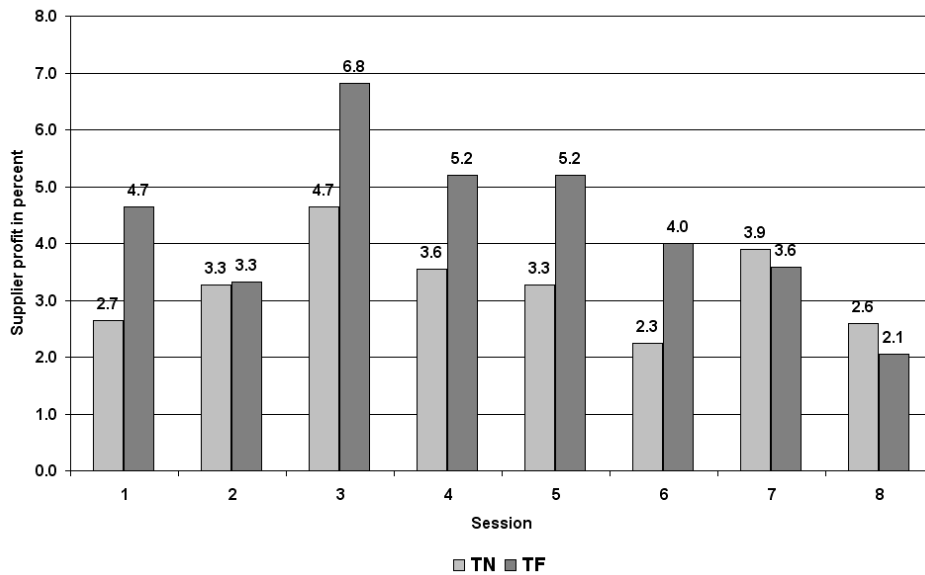


Figure 5. Suppliers' Surplus (SP)

The results are more distinct regarding the suppliers' profits. As illustrated by Figure 5, the bidders' profits are clearly higher in treatment *TF* in five sessions than in *TN*. In three sessions, the profits are equal to or larger in treatment *TN* than that in *TF*, but the differences are small. On average, the suppliers' profits are roughly 30 percent higher in treatment *TF* than in *TN*. However, the difference in suppliers' surplus is only weakly significant (MWU, 2-tailed: $N = 16$, $U = 14.5$, $p = .07009$).

Observation 2

Suppliers successfully use the additional information about buyers preferences and make (partly significantly) more profits, but not at the expense of the buyer, whose utility does increase slightly yet non-significantly with preference revelation.

According to Table 1, Pareto inefficiencies, measured by the number of Pareto-improving bids remaining at the end of an auction, are low in treatment *TF*. In three of the five Pareto inefficient outcomes, three Pareto-improving bids could have been submitted. Only in session 2, with two inefficient rounds, did more than three Pareto-improving bids remain.

The number of Pareto efficient outcomes are significantly lower in treatment *TN* compared to treatment *TF* (Fisher exact test, 2-tailed: $N = 32$, $p < .01$). Concerning the Pareto inefficiencies, the average number of Pareto-improving bids in treatment *TN* is two times as high as in treatment *TF*. Pareto inefficient winning bids are on average less than four bids away from the efficient winning bid in *TF* and more than seven bids away in *TN*. Both observations are significant (MWU, 2-tailed: $U = 10$, $N = 32$, $p = .018$ and $p = .018$, respectively).

In order to analyze whether individual or group idiosyncrasies account for the Pareto efficient outcomes in treatment *TN*, Table 2 shows individual bidder's relative performance in columns I-V and the performance of groups as R_1 . The data suggest that the effect of group idiosyncrasies on efficiency is low. The difference in proportions of Pareto efficient outcomes per group to the maximum number of Pareto efficient bids is not significant (Chi-square, 2-tailed: $X^2 = 8.0808$, $df = 7$, $p = .326$). To the contrary, Pareto efficiency does not seem to depend on a particular group of subjects, but on individual bidders. Two of the 40 bidders submit a Pareto efficient technical specification in each of the last four rounds and eight bidders submit a Pareto optimal specification in three of the four rounds. These high performance bidders account for 32 or 44.4 percent of the 72 submitted Pareto efficient bids, which indicates that Pareto efficiency depends on individual bidders. The high performance bidders are assigned to different sessions and to different cost schedule sequences, i.e., very little if any effect of the sequence of the cost schedules and the group assignment on Pareto efficiency of bids exists.

Table 2. Individual Bidders' and Group Performance in Treatment TN

Session	B	B_1	R_1	I	II	III	IV	V
1	20	6	.30	1 (.25)	3 (.75)	0 (.00)	1 (.25)	1 (.25)
2	20	10	.50	3 (.75)	1 (.25)	1 (.25)	3 (.75)	2 (.50)
3	20	10	.50	2 (.50)	1 (.25)	3 (.75)	2 (.50)	2 (.50)
4	20	7	.35	4 (1.0)	0 (.00)	0 (.00)	1 (.25)	2 (.50)
5	20	11	.55	2 (.50)	2 (.50)	3 (.75)	1 (.25)	3 (.75)
6	20	8	.40	1 (.25)	2 (.50)	3 (.75)	1 (.25)	1 (.25)
7	20	7	.35	2 (.50)	2 (.50)	0 (.00)	1 (.25)	2 (.50)
8	20	13	.65	2 (.50)	4 (1.0)	2 (.50)	2 (.50)	3 (.75)
Total	160	72		17	15	12	12	16
Median		9.0	.50	2.0 (.50)	2.0 (.50)	1.5 (.38)	1.0 (.25)	2.0 (.50)
Mean \bar{x}		9.0	.45	2.13 (.53)	1.88 (.47)	1.50 (.38)	1.50 (.38)	2.00 (.50)
Std dev s		2.39	.12	.99 (.25)	1.25 (.31)	1.41 (.35)	.76 (.19)	.76 (.19)

Note: B : Number of submitted bids. B_1 : Number of Pareto efficient bids per group. R_1 : Group performance, R_1 relates B_1 to B . I-V: Bidders with identical production cost schedule sequences.

Observation 3

In a multi-attribute English auction, Pareto efficiency is higher if the buyer's preferences are known by the suppliers prior to the auction. Pareto efficiency depends on the performance of individual bidders, but not on group idiosyncrasies or assignment to cost schedule sequences.

Concluding Remarks

The laboratory study presented here compares procurement by a multi-attribute reverse English auction in the cases of non-disclosure and full disclosure of buyer's preferences in the form of a scoring rule. The scoring rule is revealed by means of a printout of the buyer's utility for combinations of the two non-price attributes and the price and by a decision support tool embedded in the bidding screen. In case the scoring rule remains non-disclosed, bidding is an unguided, explorative process in which bidders are assumed to apply an ad hoc, trial-and-error strategy and which is less likely to lead to efficient outcomes than in the case where the buyer reveals her preferences.

The study finds that preference revelation by the buyer leads to a higher efficiency and Pareto efficiency of auction outcomes and is thus in line with earlier experimental evidence (Koppius 2002). In cases where preferences are revealed, the suppliers are better off, although the experimental evidence is weak. At least, the buyer's fear of being exploited seems unfounded, since the buyer's utility slightly but insignificantly increases when preferences are revealed.

Note that the present study ignores the (transaction) costs of participating in a procurement auction. Given the complexity of multi-attribute bidding procedures, participation is conjectured to be costly at least in terms of cognitive efforts and informational load. A buyer can make the auction more attractive for suppliers by fully revealing her preferences, since preference revelation adds value to the market and thus makes the market more attractive for suppliers' entrance. Attracting more suppliers to compete in an auction increases the level of competition, which has been shown to increase the auctioneer's revenue in standard price auctions (Milgrom 1989) and is, therefore, likely to increase the buyer's utility in a multi-attribute reverse English auction as well.

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