Information Revelation in Multi-Attribute Reverse Auctions: 
An Experimental Examination

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Abstract
This study experimentally examines the effects of information revelation in multi-attribute reverse auctions. In particular, two treatments are carried out: revelation of limit-sets which indicate the admissible bids, and revelation of limit-sets and winning bids. The results show no significant difference between the auctions with different information revelation in terms of allocative efficiency, joint gain, outcome equity and the bidders’ profit. The buyer’s profit in the auctions providing winning bids was, however, significantly higher than those auctions with limit-sets only. The latter auctions required more bids and rounds, but the bidders’ concessions were much smaller. This indicates that the disclosure of winning bids leads to quicker convergence with larger concessions. It was also found to reduce the differences in subjective outcomes between the winner and non-winner groups.

1. Introduction
E-procurement is a key component in B2B commerce, through which businesses obtain goods and services [1]. With advanced ICTs, e-procurement can improve the traditional procure-to-pay processes and increase the efficiency and effectiveness. Given its advantages, e-procurement applications have been growing fast and continuously during the past decade. The market has reached $5 billion and an annual growth rate of 8% to 12% is predicted [2].

Reverse auctions are an important e-procurement exchange mechanism. In these auctions the buyer organizes an auction and the sellers (suppliers) submit bids. Reverse auctions have been shown to achieve an average gross savings of 5-20 percent [3].

Most auctions are concerned with a single attribute, typically price. However, organizations are also often interested in values of attributes other than price. A survey by Ferrin and Plank [4] found that over 90% of purchasing managers based their decisions on both price and non-price variables (e.g., durability, service, lead-time, and trust). Typically, these types of decisions have been made through negotiations; procurement managers negotiated with a few suppliers in order to select one of them. Negotiation, however, is a difficult and costly process, in particular when one needs to negotiate with many counterparts.

Several approaches to extend auctions to multi-attribute transactions have been proposed [e.g. 5, 6, 7]. The two concerns in designing multi-attribute auctions are preference representation and information revelation [8]. Some methods aim at combining price with the total costs of all non-price attributes, others in aggregating all attributes into utility functions. Existing reverse auction mechanisms require revelation of buyer’s preferences [6, 9].

Information revelation as an important aspect in mechanism design because it can be used to control bidder’s knowledge about the buyer’s interests and preferences [10, 11]. Recent research has put effort into examining the effects of information policies [e.g. 12, 13], though only few studies have investigated the effects in multi-attribute auctions [8, 14, 15].

The present study employs a multi-attribute reverse auction system as a test bed which allows for the implementation and manipulation of different rules of information revelation in the same software environment. The effects of these different rules are examined, controlling the context (e.g. characteristics of transaction tasks and participants. This allows us to study the influence of information revelation on the transaction process and outcomes.

A laboratory experiment with two treatments was carried out: information on permissible bids only and information on both permissible bids and winning bids. The outcomes are examined with both economic and subjective measures.

The rest of this paper is organized as follows. Section 2 reviews literature on information revelation. Section 3 presents the multi-attribute reverse auction system which is used in this study. Section 4 formu-
lates the research model and hypotheses. Section 5 describes the experimental design and procedure; it is followed by Section 6 with presentation of data analysis and results. Section 7 discusses the implications and limitations of this study.

2. Relevant literature

Information has been widely studied and its value in decision-making has been acknowledged [16, 17]. In market exchange, the information about opponents is crucial and affects the participants’ behavior and outcomes [18-20]. The choice of information policy has become an important issue in procurement [21, 22].

The next section outlines the key differences between information used in auctions and other mechanisms. A summary of typical rules of information followed by review of the experimental studies are given.

2.1 Information in mechanism design

Specification of information which users of an exchange mechanism provide to and obtain from is one of the key aspects of mechanism design. Hence, mechanisms vary in terms of the rules on information, i.e. who knows what at what time [11, 23].

In auctions, the type of information that the mechanism accepts from and returns to bidders is structured and known to them. Also, it is made available to all bidders at the same time [24]. The mechanism provides information that pertains to the bid-taker. In single-attribute auctions, it is often sufficient to inform bidders about the winning bid because this bid is the best one for the bid-taker. In multi-attribute auctions, the winning bid may not produce sufficient information for bidders to make subsequent bids. Bidders may obtain information on the bid-taker’s preferences prior to or during the auction [14, 25].

In other exchange mechanisms, the form and type of information may be ill-defined and ill-structured [23, 26]. Each participant may obtain different information, request other information, and provide different types of information to other participants. This is not the case in auctions, in which bidders cannot make requests for information and cannot provide information other than specified by the mechanism.

2.2 Rules of information revelation

A common concern in multi-attribute auctions pertains to information that is revealed to the bidders. The minimum requirement is that the information be sufficient for the bidders to make bids. This may lead to bidders’ inability to bid progressively, so that consecutive bids are increasingly better for the buyer.

The revealed information may be directly or indirectly related to the buyer’s preferences in one or a combination of the following four forms.

1. Information about buyer’s preferences [6, 9]: This may be fully or partially revealed, and it may be revealed before or during the auction;
2. Information constraining the admissible bids [8, 14]: This concerns directions for allowable values of some or all attributes, constraints which provide limits on attribute combinations, bounds, etc.;
3. Information about bids [25, 27]: The bidders may obtain detailed information about the winning bids, selected bids, or all bids; and
4. Information of bids’ values [8, 28]: This may be the values of attributes only, the internal values (e.g., price, cost), or an aggregated value of bids.

2.3 Impact of information revelation

Experimental studies on different rules of information revelation have shown that they affect bidders’ bidding strategies, market competition, and the outcomes for both buyers and bidders.

Bichler [6] conducted several experiments in which the bidders were given the buyer’s value function. The results show that in this setting, multi-attribute auctions do not provide substantial benefits over comparable single-attribute auctions in terms of efficiency. In other words, even with fully-revealed utilities the additional complexity may outweigh the gains. While this may be the case, multi-attribute auctions allow for the exchange of goods that single-attribute auctions do not.

Koppius and Van Heck [25] conducted experimental studies on the impact of information availability on efficiency. The information availability specifies the type of information that is given and when, how and to whom it becomes available during the auction. They studied two types of multi-attribute English auctions: (1) auctions with unrestricted information availability, in which suppliers are provided with the winning bid, the corresponding bidder and the rating of losing bids; and (2) auctions with restricted information availability, in which the bidders are informed only about the winning bid and corresponding bidder. Their experiments show that auctions with unrestricted information availability yield higher efficiency than auctions with restricted information availability.

Strecker and Seifert [27] analyzed the impact of preference revelation schemes on the efficiency of multi-attribute English and Vickrey auctions. They concluded that English auctions with revealed preferences of the buyer are more efficient than Vickrey auctions and also, English auctions with hidden preferences. In a recent study [14], the bidders were provided...
with restricted information regarding the buyer’s utility function: (1) indicative verbal information on the monotonicity constraints of the buyer’s scoring rule, and (2) the attribute values of winning bids. The results show that revealing the buyer’s preferences increases allocative efficiency and the bidders make more profits while the buyer’s utility increases slightly.

Chen-Ritzo et al. [9] introduced a multi-attribute English auction where only partial information about the buyer’s utility function was revealed. They showed that this variant performs better in terms of efficiency than a single-attribute auction. The outperforming of the multi-attribute over the single-attribute auction holds even though the bids in the multi-attribute auction were far away from solutions predicted by theory. Notably, complexity in the auction mechanism consumes some of the efficiency gains over price-only auctions. This observation however, contradicts the findings reported by Bichler [6].

In the framework proposed by Bellosta et al. [8], the information imparted by the buyer depends on the way she represents her preferences. When the representation includes a linear additive utility function, the owner passes this utility and its lower bound. When the preferences are represented as a lexicographic aggregation model or a Tchebychev function, then the owner passes bounds imposed on the attribute values. This dependency is difficult to implement when the buyer does not make her preference model public [29, 30].

Teich et al. [31] suggest an information revelation rule in which the buyer prescribes a preference path; an ordered set of combinations of prices and non-priced attributes. The preference path begins with an anchor point and the rule specifies that a point further from the anchor is preferred by the owner over the point that is closer to it. This allows the sellers to decrease the worth of their bids (as seen by the buyer) by proposing a combination that is more preferred by the buyer than that combination previously proposed. Burmeister [29] notes that one drawback of this method is the imposition of a restriction on bidders’ choices, i.e., they are only allowed to bid on the preference path. Another limitation is the possibility for sellers to use the preference path to re-construct the buyer’s value function.

Review of relevant literature indicates that every auction mechanism requires the disclosure of the buyer’s preferences in order to provide sufficient information to bidders to make progressive bids. Disclosure of preferences, however, is problematic when the buying organization views these preferences as secret; disclosing them may endanger their competitive position.

3. Multi-attribute reverse auction system

A multi-attribute reverse auction system (Imaras) is used to study the effects of information revelation. The design and architecture of the system is available in [32]. The approach to preference representation and information revelation is introduced in next section; it is followed by the demonstration of bidders’ user interface through which different information is revealed.

3.1 Preference representation and information revelation

Auction mechanisms assume that bidders have certain knowledge about the buyer’s preferences, which may be represented in different forms and informed in different ways. There are two main types of preference representation methods [33, 34]: compensatory methods, which include additive value functions based on multi-attribute utility theory (MAUT); and non-compensatory methods, which include attribute lexicographic ordering and the Tchebychev measure. Both methods have been used in designing multi-attribute reverse auctions [e.g. 5, 8]. The challenges remain when buyers do not make their preferences public, as it is often the case in the real-world [29, 30]. In this paper we assume that the buyer uses a compensatory model.

It is important to distinguish between a buyer’s preference representation and preference information revelation, so that the disclosure can be controlled.

The buyer constructs space in which alternatives can be evaluated (e.g., utility or multi-criteria space). Using this space the buyer can, for every alternative, determine sets that dominate this alternative, sets which are dominated by it, and sets that are indifferent. This property is at the core of Imaras. At the beginning of every round, the system determines sets which dominate the winning bid in the previous round.

Giving the bidders full information about dominating sets would disclose the buyer’s preferences partially (in nonlinear cases) or fully (in linear cases). Therefore, the degree of disclosure is controlled by the buyer so that it is possible to move from giving the bidder the ability to re-construct the buyer’s preferences to having preferences completely hidden, making their re-construction impossible. The result is that bidders obtain bounds on the attribute values. These bounds are used to construct limit-sets (e.g., a three-attribute limit-set may be that price is not higher than $1000, lead time is no longer than 60 days, and warranty is not shorter than 36 months). After every round the limit-sets are re-calculated and new limits are given to bidders. The number of limit-sets generated at any time depends on the auction design model.

The revelation process outlined above allows bidders to bid similarly as they would bid in a single-attribute auction. The difference is that in a single-attribute auction bidders implicitly know the direction
of attribute value that the bid-taker prefers while in Imaras this information is given to them explicitly.

3.2 Imaras user interface

The information revelation in auctions can be controlled by the display of different information on the user interface for bidders in Imaras. Figure 1 demonstrates the user interface for bidders with both limit-sets and winning bids.

![Figure 1. Imaras user interface for bidders](image)

There are four main components:
A. The auction clock shows the time from the beginning of the auction and the time left to the deadline.
B. The navigation bars are located on the right-hand side where links to active pages are listed and the round number and clock are also shown.
C. The most recent bids are shown in both tabular and graphical forms. Here, both the bidder’s own bids (in blue) and the winning bids (in red) are displayed.
D. The bidders can see the limit-sets and make bids. The bidder can either formulate a bid based on the limit-sets or choose a bid from the list of bids generated by a given value. In both cases, the bid needs to conform at least one of the limit-sets.

Here, three limit-sets are provided. The bidder can select one set and then choose admissible attribute values for the given set. Then the selected values will appear in the bid submission table to compose a complete bid for submission.

4. Research model and hypotheses

This study examines the effects of information revelation on the process and outcomes of auctions. Figure 2 presents a conceptual model of this study, which will be discussed in the following sections.

![Figure 2. Research model](image)

4.1 Variables and measures

As shown in Figure 2, the independent variable is the level of information revelation. The levels of information revelation are manipulated in three treatments:

(1) Treatment 1 (T1): Limit-sets only, where only the limit-sets and the bidder’s own bids are revealed during the auction process; and

(2) Treatment 2 (T2): Limit-sets with winning bids, where the current winning bids are revealed, as well as the limit-sets and the bidder’s own bids.

Both economic and subjective measures are used to measure the effects. Economic indicators have been mainly used to measure individual and market performance in experimental and behavioral economics [35, 36]. Recent studies have also considered the participants’ subjective responses [15, 37].

In particular, the following economic measures are used to analyze the transaction process and outcomes [6, 14, 25, 27], including:
- Number of bids: this refers to the bids submitted during the auction process. At the individual level, it is the number of bids submitted by each bidder; at the transaction level, it is the total number of bids submitted in the same auction.
- Total concession: this refers to the value of bids that the bidders submit during the process. The total concession is the value difference or compromise that a bidder made through the auction process. It indicates the level of competition in auction.
- Convergence speed: this is the actual auction length, i.e. the amount of time to close the auction. It indicates how fast an auction reached a result.
- Economic outcomes: the economic outcomes of the contract resulted from an auction can be measured based on the buyer and suppliers’ utility or value. This study considers the buyer’s and suppliers’ revenue and profit, their joint gain, Pareto optimality, allocative efficiency and outcome equity. The revenue is measured with a rating value on a scale of 0-100, and the profit is the difference between the revenue and the break-even point (i.e. cost and revenue are equal; there is no net loss or profit).
Auction mechanisms are implemented in e-procurement systems. Bidders, as participants of the auctions, are also the users of such systems. Users’ perceptions of the process and outcomes may affect their evaluation of the mechanisms. Satisfaction has been a surrogate of effectiveness of information systems [38], and has been used in the assessment of various types of systems, including e-auctions [39]. A multi-dimensional scale of participants’ satisfaction in e-markets has been developed, including: outcomes, self-performance and process [40]. The scale is adapted to procurement auctions in this study.

4.2 Hypotheses

Information about bids is not explicitly related to the buyer’s preferences. However, bidders may be able to discover the buyer’s preferences by comparing their own bids and other available information (e.g. winning bids). In theory, the more information that is disclosed in an auction, the better the market performance will be in terms of efficiency (e.g. convergent speed and buyer’s profit). Empirical results, however, were mixed with regard to revealing buyer’s preferences [6, 9, 27]. Other studies found that higher levels of information revelation led to better market efficiency [25]. Studies on information transparency have also found that available market information on products and services from different suppliers increase market competition and thus cost savings [19, 20]. With the higher level of competition, the suppliers need to make larger concessions to bid against each other. Thus,

H1: An increase in the level of information revelation will lead to ...

A. smaller number of bids,
B. larger concessions,
C. faster convergence speed, and
D. better economic outcomes.

Revealing more information may also increase the knowledge of the bidders about the buyer’s preferences, which may lead to better joint outcomes and allocative efficiency [9, 25]. Moreover, more information revealed by the buyer may also increase the transparency of the process and thus the trust of the bidders [41]. Information about winning bids is valuable during the auction process; revealing such information may lead to better buyer-supplier relationships [42]. Users’ evaluation of systems is affected by their performance and outcomes [43]. A higher level of information revelation reduces the bidders’ effort during the process, leads to better economic gains, and develops better relationship. Thus,

H2: An increase in the level of information revelation will lead to better subjective outcomes.

5. Experiment

A laboratory experiment was conducted to examine the effects of information revelation. The experimental design and procedure are described, including: the treatments, task, subjects and instrument.

5.1 Experimental design

The experiment was conducted in a laboratory setting where the participants used Imaras to fulfill a procurement transaction. The two treatments are manipulated by displaying different information on the bidders’ user interface (Figure 1).

A business case was used as the task, which involves contracting between a milk producer and several transportation service providers. Three attributes of the transportation service were concerned: (1) standard rate; (2) rush rate; and (3) penalty for delay. There were six option values for each attribute, consisting of 216 alternatives in total.

The bidders play the role of a sales representative for one of the providers. They are competing with each other through the auctions in order to win the contract. Each contract can be awarded to only one provider. The preferences are explained in the case (private information which is not known to the other bidders). The reservation and aspiration levels of each company are also indicated in their private information. The buyer’s preferences were unknown to all bidders, and the bidders could learn the buyer’s preferences only through the information revealed in the auction.

The “theoretical winner” for the contract is Universal Inc. (represented by “Nart”), who can bid as low as 10 (the company’s break-even point) to provide the best offer to the buyer (yielding rating 92). However, because of the use of limit-sets in the mechanism design, in some situations this efficient alternative may be made inadmissible. If Worldwide Inc. (represented by “Peeka”) makes a pre-emptive offer at its reservation level (yielding rating 15) which has rating 90 for the buyer, then the subsequent limit-set may remove some alternatives ranked between 90 and 92 even though they are better for the buyer. In that case Worldwide rather than Universal becomes a winner.

The distribution of the feasible solutions (or alternatives) between the buyer and each supplier can be identified based on their preferences. This is used as references when measuring the participants’ performance (e.g. the distance from the maximum achievable contract and profit).

5.2 Experimental procedure

The participants were undergraduate students re-
recruited from in the business school of a large Canadian university, while no buyers were required. They were taking an introductory course of management information systems. The experiment as part of their course work on e-procurement was worth 6% of the total mark, considering both participation and performance.

The participants first sign up for the experiment and their demographical information is gathered via a registration form. The participants are randomly matched up and assigned to consecutive sessions for the auctions. Each session lasts one hour and forty minutes, including the time for preparation and questionnaires.

During the experiment, the participants first read the public information of the case (contextual information of the transaction) and the private information (preferences, constraints and objectives). This is followed by a pre-questionnaire before the auction, which contains three sets of questions: perceptions of the transaction task, aspiration and reservation levels. This examines the participants’ expectations of the bidding space (the alternatives they may bid) and the contract. The auction lasts 50 minutes at most, during which the participants submit bids on behalf of the companies they represent. Once the auction closes, they are asked to fill out a post-questionnaire that collects subjective responses of the process and outcomes. The participants report their evaluation of the auction process in terms of performance, effort and experience. When they assess the outcomes and performance they may refer to their expectations.

The participants’ activities during the transaction process are recorded in a database, which is used to analyze the transaction process and economic outcomes. The measures include:

- Transaction process: number of bids, number of rounds, total concession (both individual and transaction levels), time spent and convergence speed (at the transaction level);
- Economic outcomes: supplier’s revenue and profit, buyer’s revenue and profit, allocative efficiency, joint gain, and outcome equity.

6. Data analysis and results

There were 179 students who participated in the experiment, among them four records were removed from the data as their auctions were terminated accidentally. The subsequent analyses were then based on a sample with 175 participants. There were 26 auctions for T1 and 21 auctions for T2. On average, each auction involved 3.78 bidders and no significant differences were found between the two treatments in terms of number of bidders.

Most of the participants were between 20 and 25 years old as they were undergraduate students. About 45% were female and neither differs across the treatments and groups. The participants perceived their English proficiency and knowledge about auction above average, and about 75% had never used an auction system nor participated in such experiments previously. No significant difference in their understanding of the case and expectations of the transaction task was found using ANOVA.

6.1 Process and economic outcomes

The process efficiency can be measured by number of bids, number of rounds and time spent in the auction. They indicate the convergence of the auction with the time and effort the bidders spent in the auctions. Also, the opening bid and closing bid are also indicators of auction convergence in terms of the bidder’s revenue. These variables were calculated at both the individual and transaction (or auction) level (Table 1).

<table>
<thead>
<tr>
<th>Table 1. Comparison of auction process</th>
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<tbody>
<tr>
<td></td>
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<tr>
<td></td>
</tr>
<tr>
<td>T1</td>
</tr>
<tr>
<td>No. of bids</td>
</tr>
<tr>
<td>No. of rounds</td>
</tr>
<tr>
<td>Time spent</td>
</tr>
<tr>
<td>Opening bid</td>
</tr>
<tr>
<td>Closing bid</td>
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</tbody>
</table>

At the individual level, the result shows that significant effort was made by the bidders in T1 than in T2. The bidders who were given only the limit-sets and their own-bids proceeded to later rounds and spent longer time. On average, about one more round was required in those auctions. But interestingly, the same bidders did not make a large concession as those in the auctions with both limit-sets and winning bids. The winners played quite similarly in the two treatments, whereas the non-winners in T1 significantly took more rounds and time but made much less concession (over 13% on average) than the bidders in T2.

This result may indicate that the bidders did not find the limit-sets sufficient to make efficient bids. It may also indicate that the winning-bid information might provide more clues about the buyer’s and other bidders’ preferences and thus the bidders could bid more efficiently. Also, the fact that no differences on the opening bids but big differences on the closing bids indicate that the extra information—winning bids—given during the auction increased the competition levels and thus lead to quicker convergence with larger concessions.

At the transaction level, both the opening bid and the closing bid were significantly lower in T2 than in T1. However, there were no differences on the number...
of bids and rounds through which the auction converged. Auctions in both treatments were converged within eight rounds, given the initial maximum number of rounds up to ten.

The bidders obtained information about the break-even point and were told that they should not bid below this point because it would result in losses for their company. This was stated both in the case and again in the quiz administered to the participants. Nonetheless many winners were overbidding, on average.

To provide comparable values for the winning bids from different bidders (roles) we calculated both the revenue and profit for the bidders and the buyer. In both treatments, the winners were overbidding which resulted in negative profit (Table 2). Relatively, the winning bids in T2 were lower than those in T1. The effect was that the buyers increased profit from 72.48 in T1 to 80.48 in T2. This may be due to the same reason that the information with winning bids led to “tough” bids and larger concessions.

### Table 2. Comparison of economic outcomes

<table>
<thead>
<tr>
<th></th>
<th>T1</th>
<th>T2</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bidders</td>
<td>Revenue</td>
<td>15.77</td>
<td>7.14</td>
</tr>
<tr>
<td></td>
<td>Profit</td>
<td>-2.12</td>
<td>-9.52</td>
</tr>
<tr>
<td>Buyers</td>
<td>Revenue</td>
<td>88.08</td>
<td>96.48</td>
</tr>
<tr>
<td></td>
<td>Profit</td>
<td>72.48</td>
<td>80.48</td>
</tr>
<tr>
<td>Joint gain</td>
<td>Revenue</td>
<td>103.85</td>
<td>103.62</td>
</tr>
<tr>
<td></td>
<td>Profit</td>
<td>69.96</td>
<td>70.95</td>
</tr>
<tr>
<td>Outcome equity</td>
<td>Revenue</td>
<td>0.25</td>
<td>0.09</td>
</tr>
<tr>
<td></td>
<td>Profit</td>
<td>0.12</td>
<td>-0.10</td>
</tr>
<tr>
<td>Allocative efficiency</td>
<td>59.82</td>
<td>68.04</td>
<td>.17</td>
</tr>
</tbody>
</table>

We also calculated the optimal efficiency using the number of alternatives dominating the winning bid, that is, these alternatives yield a higher profit for the winning bidder, the buyer or both, and for none of them the profit is lower. The winning bids made in T2 were, on average, more optimal. The winning bids made in T1 were less optimal. Nevertheless, it shows no significant difference of the allocative efficiency between the treatments.

Considering the contract value for both the buyer and the service provider who won the contract, the joint gain and outcome equity by both their revenue and profit were compared between the two treatments. The results show little differences on joint gain and also on outcome equity in the auctions.

In addition, the winners’ roles were checked to verify whether the theoretical winner would win the contract. Table 3 summarizes the number and percentage of winners and non-winners with their roles.

The result shows that “Nart” as the theoretical winner, indeed achieved the highest percentage of wins in both treatments, whereas the percentage was much higher than other roles in the auctions with winning bids revealed (42.9%). In the non-winner group, “Nart” was the lowest in T2 but not in T1. This indicates that the winning bids enlarged their advantages. “Peeka” as another potential winner, however, performed only as well as “Nart” in T1 for both winners and non-winners. This implies that the theoretical winners won when only the limit-sets were revealed. Also, “Peeka” had little chance to dominate other bidders when the winning bids were revealed, which might be due to the higher competition and overbidding.

### Table 3. Winners/non-winners and their roles

<table>
<thead>
<tr>
<th></th>
<th>Winners</th>
<th></th>
<th>Non-winners</th>
<th></th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cres</td>
<td>T1</td>
<td>6</td>
<td>7</td>
<td>13</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>%</td>
<td>23.1</td>
<td>33.3</td>
<td>27.7</td>
<td>27.8</td>
</tr>
<tr>
<td>Nart</td>
<td>T2</td>
<td>7</td>
<td>9</td>
<td>16</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td>%</td>
<td>26.9</td>
<td>42.9</td>
<td>34.0</td>
<td>26.4</td>
</tr>
<tr>
<td>Peeka</td>
<td>T1</td>
<td>7</td>
<td>3</td>
<td>10</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td>%</td>
<td>26.9</td>
<td>14.3</td>
<td>21.3</td>
<td>26.4</td>
</tr>
<tr>
<td>Rito</td>
<td>T2</td>
<td>6</td>
<td>2</td>
<td>8</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>%</td>
<td>23.1</td>
<td>9.5</td>
<td>17.0</td>
<td>19.4</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>26</td>
<td>21</td>
<td>72</td>
<td>56</td>
</tr>
</tbody>
</table>

**6.2 Subjective outcomes**

Besides the economic measures, the participants’ responses to the post-questionnaire were used to examine their evaluation of the auction process and outcomes. A factor analysis was first conducted to in order to obtain fewer measures that can be aggregated from the items and used to compare participant’s perceptions in the two treatments. We used the maximum likelihood analysis with the oblimin rotation to identify the factors. The result extracted over 77.5% variance, and the factor loadings for all items were above 0.63. The factor loadings were then used as the weights to calculate a weighted sum for each factor from the participant’s responses. In addition, one single-item was used to measure the perception of other bidders’ competitiveness, and four items were used to measure the participant’s overall experience or satisfaction.

In order to test the effects of the information revelation, we compared the overall groups, the winner groups and the non-winner groups across the two treatments with the ANOVA techniques. The results indicate that there was little difference between the two treatments in terms of participants’ satisfaction and perceptions. A further investigation was conducted through group comparisons.

**6.3 Group comparison**

A comparison between winners and non-winners
within each treatment was conducted to explore other possible factors that may affect the auction outcomes.

Although there were no differences between the participants in the two treatments in terms of their demographics, surprisingly the winners’ experience with auction systems was significantly lower than the non-winners in T1. In T2, the winner’s expected reservations were marginally higher than the non-winners.

Similar to the pattern as the comparison of the process between treatments, the number of bids and rounds and the closing bid were significantly different between the winners and non-winners within treatment (Table 4). While it took much more effort in T1 than in T2, the winners in both treatments were bidding in more rounds than the non-winners. They also made much lower closing bid in order to win the auctions.

### Table 4. Winners/non-winners within treatment

<table>
<thead>
<tr>
<th></th>
<th>T1</th>
<th></th>
<th>T2</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Winner</td>
<td>Non-winner</td>
<td>Sig.</td>
<td>Winner</td>
</tr>
<tr>
<td><strong>Process</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. of bids</td>
<td>7.58</td>
<td>6.03</td>
<td>.02</td>
<td>6.67</td>
</tr>
<tr>
<td>No. of rounds</td>
<td>7.92</td>
<td>6.85</td>
<td>.09</td>
<td>7.05</td>
</tr>
<tr>
<td>Time spent</td>
<td>32.27</td>
<td>27.74</td>
<td>.15</td>
<td>29.24</td>
</tr>
<tr>
<td>Opening bid</td>
<td>75.62</td>
<td>80.86</td>
<td>.17</td>
<td>77.71</td>
</tr>
<tr>
<td>Closing bid</td>
<td>15.77</td>
<td>31.15</td>
<td>.00</td>
<td>7.14</td>
</tr>
<tr>
<td><strong>Satisfaction</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Achievement</td>
<td>3.53</td>
<td>2.75</td>
<td>.02</td>
<td>3.38</td>
</tr>
<tr>
<td>Performance</td>
<td>3.73</td>
<td>4.02</td>
<td>.23</td>
<td>3.94</td>
</tr>
<tr>
<td>Overall</td>
<td>4.21</td>
<td>4.06</td>
<td>.62</td>
<td>4.12</td>
</tr>
<tr>
<td><strong>Perceptions</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Outcome</td>
<td>1.96</td>
<td>2.33</td>
<td>.12</td>
<td>2.52</td>
</tr>
<tr>
<td>Competition</td>
<td>5.08</td>
<td>5.00</td>
<td>.81</td>
<td>4.57</td>
</tr>
<tr>
<td>System</td>
<td>4.16</td>
<td>3.62</td>
<td>.02</td>
<td>3.82</td>
</tr>
</tbody>
</table>

In Treatment 1, the winners showed a significantly higher satisfaction with their achievement, while it’s marginally significant in Treatment 2. The winners in T1 also provided more positive assessment on the system and information; however, it was not the same case in T2. This indicates that the differences of subjective outcomes between these groups were reduced when revealing the winning bids.

### 7. Discussion

This study considers the practical situations where in B2B transactions involve multiple attributes of goods or services rather than price only and wherein the buyers do not wish to explicitly reveal their preferences. In single-attribute auctions, the bidders can figure out what to bid even without giving the buyer’s preferences. In multi-attribute auctions, it is more difficult to determine what information is sufficient for the bidders to make progressive and informed bids.

The winning bids during auctions are feedback-type information provided by the mechanism that allows the bidders to learn the buyer’s preferences. Prior studies suggest disclosing more information to improve the efficiency of auction outcomes and process [e.g. 13, 25].

The present study examines the effects of revealing the limit-sets with and without winning bids in multi-attribute reverse auctions. The indifference in opening bids within each treatment indicates that the bidders were influenced only by the experimental manipulation on information revelation. Note that the non-winners in T2 made lower opening bids than those in T1, which was due to their lower expectations.

Overall, Hypothesis 1 on the auction process and economic outcomes was fully supported (A, B, C) except the outcomes for bidders (D). The results show that revealing winning bids increased the process efficiency in terms of number of rounds and convergence speed. Also, it made a significant improvement in buyer’s profit. This implies that the buyers should prefer mechanism in which winning bids are revealed.

When only given limit-sets, the bidders obtained higher revenue and the contracts were closer to the Pareto frontier. Thus, the bidders should favor T1, i.e. no winning bids disclosed. In contrast to revenue, the bidders’ profit increase was not significant. The reason is that in the treatments the winners represented different companies which had different breakeven points.

The results also indicate that non-winners worked harder in T1 in terms of number of bids/rounds and time spent. In effect, in T2, the auctions converged faster. A possible interpretation may be that for the bidders’ information about winning bids created an anchor [44]. Focusing on the anchor, these bidders might not explore the limit-sets and search for the best possible feasible alternatives.

Bidders who did not have information on winning bids had to rely on the three limit-sets and either use one of them select a bid or decide on the revenue value and use it to generate possible bids. It is likely that this process required more effort and ultimately it could lead to better results.

The bidders provided with the winning bids made greater concessions. If our tentative assumption of the anchoring effect is held, then the reason for the difference in concessions may be due to the bidders’ comparison of their bid and the winning bid. Under this interpretation, bidders who saw the winning bid used the difference between revenue yielded by their bid and by the winning to decide on their next bid. The other bidders may rely only on their own bid and/or limit-sets. Although the winning bid information is embedded in the limit-sets, the bidders do not know which limit-set is based on the winning bid. Therefore, they are likely to rely on own bids and seek a bid that is feasible and
yields revenue close to that of their last bid.

Prior studies have shown the complementary effects between the process efficiency and the level of information revelation [25]. Auctions converge faster when more information is provided, and more information is revealed when auction lasts longer. The present study shows that on average one round can be reduced when revealing the additional information. The underlying assumptions still rely on the bidders’ learning about the buyer’s preferences through the information revealed during the auction process.

Regarding the subjective outcomes (Hypothesis 2), the results show no significant differences between the treatments. A group comparison was conducted to further explore the effects between winners and non-winners. It shows that the non-winners had a lower level of subjective outcomes compared to the winners.

The findings imply that appropriate design of information rules in multi-attribute auctions enable bidders to operate efficiently in such complex problems. Also, due to the different interests between the buyers and bidders, specific control on information revelation may be concerned. For instance, if the anchoring effect indeed exists, then the buyers may consider creating anchors with simpler and clear information so that they can obtain better outcomes.

Several limitations of this study should be addressed for future research. In the experiment, a test bed was used by university students to conduct a simulated auction task. Research in e-business has discussed both advantages and disadvantages of this setting. Future research may validate the hypotheses and findings with a field study where the systems are used by business professionals for real life transactions. Also, the transaction is relatively complex and the number of bidders in each auction is small. This may limit the findings to those transactions that involve business contracts with only a few potential and important suppliers. Future work may consider transactions with a larger number of suppliers for simpler transactions, which may require different information policy.

8. Acknowledgements

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9. References


