Multi-attribute, Online, Descending-Price, Procurement Auctions

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Introduction

Online, industrial, procurement auctions are becoming a standard component in many companies’ purchasing toolbox. Companies seek to enjoy the benefits of the marketplace by implementing competitive bidding strategies among their supply base. Recent surveys of industry practices indicate that up to 52% use some form of online auction (Beall et al, 2003), with an average contract price above $2 million. One popular configuration for these auctions are the parallel of the English auction, conducted as online, descending-price, auctions. Industrial auctions are most suited for products with a need for moderate levels customization. A rigorous vendor qualification process is oftentimes quite selective with only a few qualified vendors invited to participate in the auction.

A second unique attribute of industrial procurement auctions, and one that justifies the current analysis, is that even when using pre-qualified vendors, vendors differ on many attributes. Clearly, price is an important differentiator among vendors. But other factors that differ across vendors and have an impact on total cost of ownership include transportation, payment terms, quality control requirements, delivery times, financial strength, and use of multiple locations. While the cost of these non-price factors may be small, relative to the scope of the contract, the difference in non-price factors may be larger than price differences.

While non-price factors are clearly important, including them explicitly in reverse auction has not been thoroughly studied. Two important aspects of non-price factors are a buyer’s disclosure policy and the method of incorporating these costs in bid evaluation. The focus of this paper is to evaluate the impact of different disclosure and evaluation policies on vendors’ bidding behavior and expected buyer cost. Using three different auction mechanisms, chosen because of their practical attractiveness, it is shown that the most common auction mechanism, the parallel of the English auction, does not lead to truthful revelation of vendor costs. Moreover this article shows that a buyer would prefer not to disclose non-price information to vendors, even if this is part of the buyer’s total cost of ownership. In those cases where the buyer discloses non-price factors, it is shown that it is in the buyer’s best interest to shave the cost disclosed to each vendor, reporting a lower cost than would actually be incurred.

Three different auction mechanisms are studied here:

1 It is assumed that all non-price factors can be monetized, either because they have direct cost implications, or their mitigation can be achieved by entering into appropriate contractual or financial arrangements (e.g., insurance).
Reverse English Auction (REA)² These auctions are conducted as online, descending-price, “button” auctions where the lowest bid determines the auction winner. In each round, the price descends and each vendor has to acknowledge whether he continues bidding or leaves. The vendor’s final auction bid is his bid price. However, the auction winner may not be awarded the contract. In awarding the contract the buyer adds the non-price factors to the final bids and chooses the vendor with the lowest total cost.

Complete Information Auction (CIA) In these auctions each vendor is notified of the non-price cost, accrued to the buyer, of accepting his bid. This cost is then reduced from the winning vendor’s bid.

Total Cost Evaluation Auction (TCEA) A hybrid of the two previous forms, in this auction the buyer does not disclose non-price factors to each vendor but adds the additional costs to each bid. Thus when competing vendors view bids, they include total cost. The vendor with the lowest total cost wins the auction and is awarded the contract, at the lowest offered total cost.

It is assumed, that under CIA and TCEA the client’s announced value of non-price factors is binding. The market-maker (either human or software) evaluates bids and pays vendors based on these announced values, even if they do not reflect the client’s true cost. Here vendors’ bids include the additional costs (non-price factors), as announced by the buyer.

The REA model is the most common format, in practice. This is the dominant format for FreeMarkets Online. Academics assume that vendors have truthful information regarding buyer preferences (Snir and Hitt, 2003, forthcoming; Scott, 2003; Streiker, 2003, 2004; Che, 1993). Since theoretical analyses of reverse auctions differ from common practice, there is a need to formally understand vendor and client behavior based on commonly used formats.

A Model of Online Auctions

A risk-neutral client is interested in procuring industrial products or services using an online, descending-price auction.³ There are \( n \) (usually between 2 and 10) prospective pre-certified vendors participating in the auction. There is no ambiguity regarding the client’s technical requirements nor each vendor’s ability to provide the product or service. A vendor’s bid is a commitment to provide products of the determined, verifiable, quality. It is assumed that all bid preparation costs and evaluation costs are sunk at the time of the auction.

Vendors are differentiated by a privately-known production cost \( c_i \), and by a client-specific, additional cost of \( a_i \), privately known only to the client.⁴ These latter costs are not required to be paid to

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² While this is often called a Reverse English auction it is modeled as a “button auction”. This provides bid information for each bidder, at each price.
³ The desired product may be either a physical product or a service, but is required to be well-defined and requires some form of customization to meet the client’s specific needs.
⁴ If there is a component of client-borne costs that can be verified by the vendor (e.g., known shipping costs) then it is included in \( c_i \), in this model.
the vendor. Production costs are assumed to be IID over \([c, \bar{c}]\) with a commonly-known cumulative distribution function \(F(c)\). Additional costs are private information to the client, and are distributed IID over \([a, \bar{a}]\). Vendors know only the cumulative distribution of additional costs \(G(a)\). Production costs and additional costs are independent of each other. A vendor’s offer includes \(c_i\), borne by the vendor, and \(a_i\), borne by the client. The online auction tool records each vendor’s lowest price as the final bid.\(^5\) Denote this bid price by \(b_i\). If vendor \(i\) wins the auction he is paid \(p_i\), determined by vendors’ bids and the auction mechanism.

The process of awarding the contract follows the stages in Figure 1

**Figure 1: Time Line**

<table>
<thead>
<tr>
<th>Stage 1</th>
<th>Stage 2</th>
<th>Stage 3</th>
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<tbody>
<tr>
<td>Client chooses mechanism</td>
<td>Online auction proceeds, based on chosen mechanism.</td>
<td>Client evaluates bids and accepts a bid.</td>
</tr>
<tr>
<td>Vendors qualified and requirements clarified.</td>
<td>Auction winner identified.</td>
<td>Contract is awarded.</td>
</tr>
<tr>
<td>(c_i) and (a_i) privately identified.</td>
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**Strategic Bidding**

Based on the information available to vendors and the auction mechanism chosen by the buyer, vendors decide how to bid. Since under some mechanisms the auction winner is not awarded the contract, vendors may have an incentive to offer a bid that differs from their true cost. Proposition 1 identifies vendor bidding in the REA auction.

**Proposition 1:** Under auction mechanism REA, vendors’ bids are higher than cost.

**Sketch Proof:** In the REA auction when the vendor with the lowest production cost \((c_{(1)})\) is awarded the contract he receives a price higher than his bid, consistent with a second price auction. However, vendor \(c_{(1)}\) is not awarded the contract when the total client cost (bid plus additional cost) is higher than a different vendor. In these cases, the vendor who is awarded the contract receives a price equal to his bid. If he bids according to his cost, he would earn zero profit. Raising his bid increases profit, with only a minor impact on the probability of winning the contract.

Proposition 1 shows that in the REA auction all vendors offer a bid higher than cost. The difference between cost and bid depends on the vendor’s cost, the distribution of \(c_i\), and the distribution of additional costs \((a_i)\). Since vendor’s bids are higher than cost \((b_i > c_i)\) this raises the question whether this

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\(^5\) This is consistent with a “button auction”.

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mechanisms always awards the contract to the lowest total cost vendor. Proposition 2 shows that the answer is no.

**Proposition 2:** Auction mechanism \( REA \) is not efficient; the vendor with the lowest total cost is not assured of the contract.

**Sketch Proof:** For any strategic bidding function \( b_i(c_i) > c_i \) where \( b_i(c_i) \) is concave there exist a set \( \{a_i\} \) of additional costs such that, if the differences between low cost vendors is sufficiently small, the vendor with the lowest total cost offers a bid that generates higher total cost than a different vendor.

In contrast to the results for the \( REA \) mechanism, mechanisms \( CIA \) and \( TCEA \) are efficient and a vendor receives a price higher than his bid, so bids equal cost.

**Proposition 3:** Under auction mechanisms \( CIA \) and \( TCEA \) bids equal cost.

**Sketch Proof:** These mechanisms are comparable to a second-price auction.

The differences between the auction mechanisms, and the methods for incorporating client-related costs, have a number of implications for strategic behavior and auction results. In the \( REA \) auction a vendor’s revenue depends on his bid and private cost \( (c_i) \) not on \( a_i \). Since a vendor’s revenue does not depend on \( a_i \), the only advantage from having a low additional cost is being awarded the contract when he does not have the lowest production cost. This leads to \( b_i > c_i \), to assure positive profit whenever the vendor is awarded the contract. However, this also leads to inefficient outcomes where the vendor with lowest total cost may not be awarded the contract. In contrast, under \( CIA \) and \( TCEA \) mechanisms a vendor’s bid, as evaluated by the client, depends on \( c_i + a_i \). The vendor is awarded the contract when this sum is lowest, but he never pays his bid. Here there is a direct advantage to having a low additional cost; it increases profit. Each vendor bids his true cost.

**Client Choice of Auction Mechanism**

One of the key results of this research is that a client’s expected cost from \( REA \) is lower than the other mechanisms. This stems from the fact that in the \( REA \) auction the winning vendor’s profit arises only from production cost advantages, not client-related costs. In the other mechanisms the winning vendor earns a profit on his relative advantage in both types of cost. With only a small number of competitors it is fairly common for the winning vendor to have an advantage in both dimensions, when compared to the next best vendor. Proposition 4 validates these results.

**Proposition 4:** Auction mechanism \( REA \) generates lower expected cost for the client and lower expected profit for the winning vendor.

**Sketch Proof:** Available from the author.

**Client Disclosure of Additional Costs**

The preceding analysis shows that the \( REA \) mechanism offers lower expected cost to the client. However, at times, the client may prefer not to use the \( REA \) mechanism. One difficulty with the
mechanism is that it is modeled here as a “button auction”, where each vendor acknowledges whether or not he is still bidding in each round, as the price decreases. This may be infeasible or inconvenient at times.

In those cases where the CIA or TCEA mechanism is employed, it is important to understand the client’s strategic behavior regarding the disclosure of non-price factors. It is assumed, in the previous analysis, that when the client chooses to disclose, the auctioneer requires the client to evaluate the bids based on this disclosed value. However, this does not require that the client disclose to the vendors the true value of $a_i$, even if the client bears $a_i$. From Proposition 4 it is clear that the client prefers not disclose the value of $a_i$. Hence, it may be that if required to disclose a value for $a_i$, the client would report a value that is lower than her true cost. Proposition 5 formalizes this result.

Proposition 5: In auction mechanisms CIA or TCEA the optimal disclosure to each vendor of his additional costs is to reveal a cost that is lower than the true cost.

Sketch Proof: In mechanisms CIA and TCEA the vendor who is awarded the contract earns a profit both from his advantage in production cost and in additional cost. By disclosing a value of additional cost, which is lower than the true cost, the client reduces the winning vendor’s profit from additional costs. The optimal disclosed value of $a_i$ trades off the reduction in vendor profit against the cost of incurring the undisclosed portion of additional cost.

The results of Proposition 4 and 5 indicate that when a client bears a private cost, which differs across vendors, it is in her best interest not to truthfully reveal this cost to the vendors. Even if the client is bound to evaluate vendors based on the announced cost, she prefers to reveal a cost that is lower than each vendor’s true cost. The result of Proposition 5 is surprising when compared to common-value and affiliated-value auctions where the client has private information of a signal. In these auctions revealing the client’s private information is in the client’s best interest (Krishna, 2002).

In conclusion, in a multi-attribute procurement auction, the client prefers to withhold information regarding client-related costs, which vary across vendors. By withholding information the client reduces the winning vendors’ profit from factors not directly under his control. This research provides a first step in prescribing improvements to current practices of conducting online procurement auctions.

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6 Note that the disclosed value for $a_i$ is binding, and the previous results do not depend on truthful disclosure.