Electronic Commerce Research and Applications 12 (2013) 181–194

Contents lists available at SciVerse ScienceDirect

Electronic Commerce Research and Applications

journal homepage: www.elsevier.com/locate/ecra

A hybrid mechanism for heterogeneous e-procurement involving a combinatorial auction and bargaining

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ARTICLE INFO

Article history:
Available online 10 April 2013

Keywords:
Bargaining
Combinatorial auctions
E-procurement
Mechanism design
Myopic best responses
Negotiation
Vickrey–Clarke–Groves mechanism

ABSTRACT

We discuss the design of a hybrid mechanism for e-procurement, which implements a multi-attribute combinatorial auction, followed by a bargaining process to achieve desirable procurement transaction outcomes. For the auction phase of the mechanism, we discuss incentive-compatible bidding strategies for suppliers, and how the buyer should determine the winning suppliers. In the follow-on bargaining phase, the buyer can implement a pricing strategy that views the winning suppliers as though they are in different groups. We develop a model and derive decision conditions for the buyer to formulate procurement strategy in this context. Our most important finding is that, compared with the classical Vickrey–Clarke–Groves mechanism, the proposed mechanism improves the *transactional social surplus*, by including the possibility of post-auction bargaining. We also consider the likelihood that such a hybrid mechanism will be able to provide sustainable business value so long as there is reasonable symmetry in bargaining power between the buyer and the supplier. We offer some thoughts on how to extend this research with approaches from behavioral economics and experimental methods.

Negotiation in the classic diplomatic sense assumes parties more anxious to agree than to disagree.
– Dean Acheson, American statesman, 1893–1971.

1. Introduction

Many processes involve decisions in which screening and refinement of the evaluation lead to a decision. This occurs in academic entrance examinations, when schools select students who qualify based on written exams, and then they interview the potential entrants in a shortlist for the remaining class positions. Similarly, for many sports competitions, athletes need to qualify in semi-final competitions, before they can compete for gold, silver and bronze medals. Multi-phase mechanisms of this sort support a better decision-making and competitive process that results in outcomes that are valuable, fair and effective.

E-procurement practices operate in a similar way. In numerous sourcing contexts, we can observe the use of an auction followed by bargaining in some form. (See Appendix A for an example in the human resource reverse auction e-procurement context.) *Bargaining* is a subset of the broader communication activities that occur in *negotiation*. Lewicki et al. (2006) distinguish bargaining as having a competitive aspect, whereas negotiation is intended to be more cooperative in nature. The latter includes different kinds of interactions different parties can have to support exchange, compromise or agreement. The former is narrower, and pertains to details of the terms reached or value exchanged (e.g., wages in labor disputes). This also occurs in *heterogeneous procurement*, in which a buyer purchases different kinds of supplies, in contrast to *homogeneous procurement* for one item. Combinatorial auctions allow suppliers to bid and serve as screening mechanisms to select among different suppliers. Subsequent interactions may involve bargaining between a buyer and sellers that establish a final price and the details of exchange (Wan and Beil 2009a). (See Appendix B for terms used in this work.)

The *bargaining phase* is important. It supports a buyer's and seller's efforts to work out the details of exchange. The estimated average savings available for a buyer when a reverse auction mechanism is used for procurement is greater than 14% (Trade Interchange 2012a). Adding a bargaining phase of buyer–supplier interaction helps to ensure the greatest value of social welfare arises from such transactions.

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1567-4223/$ - see front matter © 2013 Published by Elsevier B.V.
http://dx.doi.org/10.1016/j.elerap.2013.03.006

Prior work on combinatorial auctions in procurement mainly has considered prices and allocations (Ledyard et al. 2002, Hohner et al. 2003). Different forms of negotiation or bargaining have not been analyzed as follow-ups to e-procurement auctions. Wang (2000) explored the equilibrium strategy for homogeneous procurement in a two-phase mechanism involving an auction and bargaining. Even though the model was for one-unit purchases, it still was complicated and only explored the properties of the equilibrium. The authors' work suggested that backward induction often is intractable for the analysis of complicated bidding processes. Also, the model did not treat the buyer's concerns of supply quality. Some buyers conduct auctions, and then use the information from the auction to negotiate privately with a losing bidder by offering a *take-it-or-leave-it price*. Salmon and Wilson (2008) have suggested a *second-chance offer mechanism*, which can generate greater value for the buyer. It has a two-phase mechanism combining an auction with information sharing to enhance the joint payoffs.

Others have suggested more complex mechanisms. Nagarajan and Bassok (2008) examined a bargaining framework for decentralized supply chains in which an assembler buys complementary components from many suppliers. The buyer and suppliers act in a sequence: (1) the suppliers form supply coalitions; (2) the coalitions compete for a position in the bargaining sequence; and (3) then the coalitions bargain with the buyer. This process involves multilateral negotiation in a multi-phase mechanism. Pre-qualifying suppliers based on the quality of supplies they can deliver is costly though. Wan and Beil (2009a) allowed suppliers to delay the qualification process until after the auction. This is *post-qualification*. Tunca and Wu (2009) considered a two-phase auction process too. In the first phase, the buyer uses an auction to select the most competitive group of suppliers. In the second, the buyer adjusts the quantity and price paid to each supplier via a bargaining process. This enhances the value of the auction outcomes (Wan and Beil 2009b).[1]

We will analyze a setting in which a buyer wishes to procure heterogeneous goods with consideration given to what is an efficient level of quality. We design a *hybrid mechanism* involving an auction and bargaining. Our proposed approach includes a multi-attribute combinatorial auction, followed by bargaining on payments to ensure that the procurement transaction will finish.

In the auction phase, the buyer will select a set of winners in a combinatorial auction, and establish supply allocations for the selected suppliers, based on a targeted level of supply quality. Due to information asymmetry, the buyer will not know the cost of the various sellers' supplies at the outset. In addition, because of the computational complexity of the mechanism, the buyer will face a winner determination problem. The buyer's goal is to maximize *transactional social surplus*. It can accomplish this by achieving the best level of *allocation efficiency*: the marginal benefits of supplies should be equal to the marginal costs of production. In the bargaining phase, an equilibrium will occur when the time value of the payments the supplier receives is considered, and the true production costs of the winning suppliers.

The buyer has two options: (1) making an exchange with a supplier that include payments to recognize the transaction price established by the auction or (2) developing a workable price with post-auction bargaining. We will show that the key decision criterion for the buyer's best procurement strategy is tied to different types of winning suppliers. Compared to the *Vickrey–Clarke–Groves* (VCG) *mechanism*, our hybrid mechanism improves transactional social surplus, and supports transaction-making when the VCG mechanism fails to do so.

2. The model

We next discuss our model and then proceed with the analysis. Suppose a buyer wishes to purchase one unit of each good in a set of goods from various suppliers. Let the goods be indexed by $i = \{1,\ldots,m\}$, and the suppliers be indexed by $j = \{1,\ldots,n\}$. We propose a hybrid mechanism with two phases, a combinatorial auction phase and a subsequent bargaining phase. (Our modeling notation is presented Appendix C.)

2.1. Auction phase

The buyer will identify a set of winners, *Winners*, among the bidders and specify a targeted level of quality for all of the products. The auction is a revised VCG mechanism, which maximizes social surplus based on the sum of the surpluses generated by each supplier for the level of quality they deliver to the buyer. The objective of social surplus maximization is good for the buyer, since a first-best allocation will maximize the buyer's profit for the auction priced established and the revenue that results from bargaining. This will be clearer after we analyze the bargaining stage.

2.2. Bargaining phase

After the auction concludes, the buyer will have three possible strategies: (1) procuring from suppliers based on the auction prices; (2) bargaining with suppliers to get the suppliers more cheaply; or (3) allowing the process to finish without a purchase. The buyer will have an opportunity to bargain with the winning suppliers, based on cost information that is revealed about the supplies they offer in the auction phase through the bids they make.

2.3. Process description

In the auction phase, a supplier j, who is only willing to supply what he bids on, will bid to supply $Bundle_k$. In the spirit of the *revelation principle*, we consider a direct mechanism in which $Bid_j(Bundle_k)$ gives useful but not perfect information on the estimated production cost of the supplier for the bundle of supply goods from the buyer's viewpoint:

$$Bid_j(Bundle_k) = EstCost(Bundle_k) \tag{1}$$

Thus, $EstCost(Bundle_k)$ represents the cost function of supplier j as estimated by the buyer for the products in $Bundle_k$, based on the supplier's bid. We represent the multi-attribute combinatorial auction phase in our mechanism as:

$$QA - VCG : \{FeasAllocSet, FeasQualSet, Pmt^{Auction}\} \tag{2}$$

FeasAllocSet is the set of feasible allocations of supplies, *FeasQualSet* is the set of feasible quality levels that can be produced related to the supplies, with $FeasQualSet = FeasQual_1 \times \cdots \times FeasQual_m$. Here $FeasQual_i$ denotes the feasible quality levels that can be delivered

[1] The issue of *bargaining power* is implicit in this research, though we will not model it directly nor consider it in any great depth. There are several reasons for this. (1) Bargaining is only feasible as a second stage in the mechanism design that we will propose if there is a relative balance of power between the buyer and the supplier. If the buyer's power is too great, no supplier will wish to engage in any process involving bargaining. (2) It may be possible that the buyer's bargaining is relatively greater than the supplier's, but this still may not be sufficient to diminish the value of a post-auction bargaining phase, so long as the net value that is created can be successfully shared to enhance the social surplus that is achieved. And (3) if there is an inappropriate balance between the buyer and supplier in bargaining power terms, then the buyer will need to implement some means to subsidize the supplier over the longer term to ensure that the procurement mechanism is sustainable for the participants that are involved.