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Interfaces with Other Disciplines

Contingent payment auction mechanism in multidimensional procurement auctions

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ABSTRACT

This paper considers the auctioning of an indivisible project among several suppliers who hold private information about their own efficiency type. Both quality and price need to be determined. Different from scoring auctions, we present a new method, i.e., contingent payment auction mechanism (CPAM), which can effectively deal with the optimal procurement strategy in multidimensional procurement auctions. CPAM can implement the optimal mechanism for the buyer and is thus optimal among all possible procurement strategies. CPAM implies that the buyer should first design and announce a contingent payment function that specifies a payment for each possible quality level before the bidding begins. Compared to scoring auctions, CPAM has some advantages. It does not require a special form of scoring rule and can be generalized in a more broad auction formats. Furthermore, it can help us to solve the ex post moral hazard problem. We consider two kinds of CPAM. For the CPAM I is sensitive to different auction formats, we come up with CPAM II which can improve the performance of CPAM I. Broadly speaking, CPAM integrates the idea of dimension reduction from scoring auction into that of incentive contract design from contract theory to solve the problem of ex post moral hazard.

1. Introduction

The real-world procurement auctions in both private and public sectors allow for considering different dimensions besides price, such as technical specifications and aesthetic properties of the item to be supplied, delivery lead time, payment conditions, amount and quality of service, and supplier reliability. Such complexity introduces several important strategic issues that do not exist in a simple auction where the winner is always the bidder with the lowest cost.

In this paper, we study how the buyer should design procurement process while taking two primary attributes, quality and price, into account. The key to the above problem is the supplier's private information about her own efficiency. The buyer's objective is to design a mechanism that maximizes her expected profit, under the constraints that the suppliers' individual rationality and incentive compatibility are assured. Our model provides a simple setting to study the integration of the quality decision for an indivisible project and the discovery of its price, i.e., contingent payment auction mechanism (CPAM). Furthermore, CPAM can implement the optimal mechanism and is thus optimal among all possible procurement strategies. In CPAM, the buyer should first announce a contingent payment function, which specifies an amount the buyer will pay for each possible value of delivered quality. The buyer verifies the quality level provided by the winner and then pays to her according to the pre-announced payment function. We consider two types of CPAM in this paper (CPAM I and CPAM II). In CPAM I, the buyer first announces a contingent payment function, and then suppliers submit competitive biddings on quality offer. The supplier with the highest bid (i.e., quality offer) wins the auction, provides the delivered quality level, and receives a payment according to the pre-announced payment function. In CPAM II, the buyer also should first announce a contingent payment function. Each potential supplier then views this transaction as a business opportunity and submits a lump-sum entry fee they are willing to pay for the right to supply. The supplier offering the highest entry fee will win the auction and only the winner pays an entry fee. Subsequently, the winner provides the optimal quality level corresponding to the entry fee and receives a payment according to the pre-announced payment function.

In all, CPAM II has improved the performance of CPAM I in two aspects. Unlike CPAM II, CPAM I must be conducted in the sealed bid fashion, and would lose its optimality when implemented in other auction formats. Another distinction between the two is the amount of detail required to determine the optimal payment function: CPAM I requires the number of potential suppliers, whereas CPAM II does not. Yet more complicated in process than CPAM I, CPAM II can be more helpful to promote fair competition.

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This paper is at the intersection of scoring auctions and incentive contract auctions. The advantage of scoring auctions is that they can transform multidimensional bidding attributes into one dimensional score to help us to choose a winner, but they cannot effectively verify the implementation of the delivered offer ex post. They can assure us to choose the most efficient supplier but cannot impose enough incentive for the supplier to provide the exact goods or services ex post which she offered in the bidding process. In the scoring auctions which deal with two dimensions including price and quality, Manelli and Vincent (1995) show that such two-dimensional auctions provide high-powered incentives for price reduction but at the expense of quality. The second argument against scoring auctions is that they are often too complex to implement in practice because of their lack of transparency, their greater vulnerability to corruption, and their sensitivity to moral hazard and renegotiation (Burguet and Che, 2004). The incentive contract theory cannot handle the multidimensional offers, but it can effectively solve the problem of ex post moral hazard. In this paper, we combine the merits of these two series of auction theory to study the optimal procurement strategy, which shows how price discovery can be integrated with quality decision.

The advantages of CPAM are as follow. Above all, we do not need to design an optimal scoring rule that can convert multidimensional offers into one-dimensional score just as in the present scoring auction. Second, the scoring auction just evaluates the quality after bidding and cannot supervise the supplier's real quality provision, i.e., the winner has motive to provide lower quality level than the one he bids. In our CPAM, the buyer's ultimate payment depends on the quality level delivered by the supplier even he wins the auction, thus the buyer has discretionary power to supervise the supplier's quality provision. This contingent payment function can effectively lessen the risk of moral hazard.

There is a growing body of literature that studies procurement auctions from the perspectives of supply chain management and coordination. Procurement auctions often have characteristics quite different from most auctions analyzed in the economics literature. It is well known that a supplier's delivery or service lead time should factor prominently in the procurement decision (Hariga and Ben-Daya, 1999; Stadtler, 2005; Bottani and Rizzi, 2008). In the sourcing of a product or service, a buyer should consider both procurement price and delivery lead time. The faster a supplier's delivery lead time, the lower a buyer's operating costs (e.g., inventory holding and backorder penalty costs). A supplier's delivery lead time depends on the supplier's capacity, but capacity is costly, and so there is a classic incentive conflict within the supply chain: the supplier incurs the direct cost of capacity but the buyer enjoys its benefit. To complicate matters, the buyer often has only an estimate of the supplier's capacity cost, while the supplier knows it precisely. Some literature focus on how a buyer should design her procurement process to achieve minimum total cost through an effective balance of price and delivery lead time and also investigate the effect of the implementation of the optimal mechanism on the supply chain efficiency (Cachon and Harker, 2002; Cachon and Zhang, 2006; Ould Louly and Dolgui, 2009; Xu et al., 2010).

The other major factor the buyer needs to consider is how much to order from the supplier. Furthermore, what complicates procurement auctions is that the quantity the buyer will eventually procure might not be fixed in advance. There are also papers analyzing procurement auctions with endogenous quantity. Variable-quantity auctions were first analyzed by Dasgupta and Spulber (1990), who showed that the optimal procurement mechanism can be implemented via a price–quantity schedule. To avoid some unpleasant features of the variable-quantity auctions, Chen (2007) designed an optimal entry-fee auction in the context of a newsvendor model with supply-side competition, in which the procurement quantity is endogenously determined. Lau et al. (2008) consider a dominant retailer who will purchase a newsvendor-type product from a manufacturer contracting problem with asymmetric cost information and price-dependent demand. Li and Scheller-Wolf (2011) study optimal auction design when a buyer's procurement quantity depends on the suppliers' private cost information. Ryu and Yucesan (2010) consider a fuzzy approach to the newsvender problem. They solve the fuzzy newsvendor problem to study three coordination policies: quantity discounts, profit sharing, and buyback. Zhang (2010) differs from the above paper because he includes both supplier delivery performance and price-sensitive market demand in the buyer's maximization problem. He identifies the buyer's optimal procurement mechanism, and demonstrates that the buyer can achieve nearly optimal revenue by using the fixed service-level contract, which specifies a target service level and offers a price–quantity menu to the supplier.

In procurement auctions, governments often consider multidimensional bids that include price, quality, lead time and so on. Contrast to traditional competitive bidding literature, some papers focus on models of multidimensional auctions, where supplier bids on both price and non-price attributes, and bids are evaluated by a scoring rule designed by the buyer (Che, 1993; Von Ungern Sternberg, 1994; Bushnell and Oren, 1994; Branco, 1997; Beil and Wein, 2003; Parkes and Kalagnanam, 2005; Engelbrecht-Wiggans et al., 2007). When private information is one-dimensional, a scoring auction in which price enters linearly into the scoring rule can select the bidder with the lowest cost parameter and implements the optimal scheme. Depending on different assumptions of the cost function, the optimal scoring rule may underweigh or overweigh quality relative to the true preference of the buyer. Consequently, the buyer needs to choose a downward distortion quality level to limit the information rents collected by the low-cost suppliers. When private information is multidimensional, Asker and Cantillon (2010) show that the buyer is still interested in distorting qualities away from their efficient levels. However, the optimal scheme can no longer be implemented by a scoring auction with a scoring rule that is linear in price. Nevertheless, they provide numerical examples suggesting that such scoring auctions perform almost as well as the optimal scheme. Some articles compare the performance of different procedures: Dasgupta and Spulber (1990), Che (1993), and Chen-Ritzo et al. (2005) compare the scoring auction, which turns out to be optimal in their setting, with price-only auctions; Asker and Cantillon (2008) compare the scoring auction with price-only auctions, beauty contests, and menu auctions; Manelli and Vincent (1995) and Bulow and Klemperer (1996), Bulow and Klemperer (2009) compare (different models of) negotiation with auctions. Except for Asker and Cantillon (2008), these articles are restricted to one-dimensional private information. Most of the above papers note, once the scoring rule is given, the maximum level of social welfare a supplier can produce can be used to construct equilibrium in these auctions. Another common characteristic in scoring auction settings is that the scoring rules used in the awarding criterion should be pre-specified by the auctioneer or be given by an ex post method after the bidders have presented their offer (see for example, Lorentziadis, 2010). Moreover, whether the buyer can commit to a scoring rule will take an important effect on the auction outcomes.

Also closely related to this paper is the literature on the use of incentive contracts in auctions (see Laffont and Tirole, 1987; Riordan and Sappington, 1987; McAfee and McMillan, 1987). In these models, the principal always faces a double asymmetry of information, not knowing the exact productivity type of the firm and not observing its effort level. The principal must design a contract to address both the adverse selection (the principal does not know the expected cost of any supplier) and moral hazard (the principal