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Mechanism design for e-procurement auctions: On the efficacy of post-auction negotiation and quality effort incentives

He Huang [a,*], Robert J. Kauffman [b], Hongyan Xu [a], Lan Zhao [c]

[a] School of Economics and Business Administration, Chongqing University, Chongqing 400030, China
[b] W.P. Carey School of Business, Arizona State University, Tempe, AZ 85287, USA
[c] School of Arts and Sciences, State University of New York, College at Old Westbury, Old Westbury, NY 11568, USA

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ABSTRACT

Practical mechanisms for procurement involve bidding, negotiation, transfer payments and subsidies, and the possibility of verification of unobservable product and service quality. We model two proposed multi-stage procurement mechanisms. One focuses on the auction price that is established, and the other emphasizes price negotiation. Both also emphasize quality and offer incentives for the unobservable level of a supplier's effort, while addressing the buyer's satisfaction. Our results show that, with the appropriate incentive, which we will refer to as a *quality effort bonus*, the supplier will exert more effort to supply higher quality goods or services after winning the procurement auction. We also find that a mechanism incorporating price and quality negotiation improves the supply chain's surplus and generates the possibility of Pareto optimal improvement in comparison to a mechanism that emphasizes the auction price only. From the buyer's perspective though, either mechanism can dominate the other, depending on the circumstances of procurement. Thus, post-auction negotiation may not always be optimal for the buyer, although it always produces first-best goods or service quality outcomes. The buyer's choice between mechanisms will be influenced by different values of the quality effort bonus. For managers in practice, our analysis shows that it is possible to simplify the optimization procedure by using a new approach for selecting the appropriate mechanism and determining what value of the incentive for the supplier makes sense.

1. Introduction

The use of electronic auctions in supply chain procurement has grown dramatically in the past 15 years with the advent of the Internet in support of electronic commerce, putting new demands on economists and supply chain managers to blend the capabilities of economics and engineering (Roth 2002, Varian 2002). It also requires technologists, behavioralists and methodologists to build a shared base of knowledge from analytical modeling and experimental work, computational analysis and simulation, and algorithm development for agent-based systems and artificial intelligence (Gimpel et al. 2008, Kersten et al. 2008, Jennings et al. 2001, Parkes and Kalagnanam 2005, Smith 1982).

In 2007, Aberdeen Group reported that the enterprises they studied used e-procurement to: improve requisition-to-pay process efficiency; achieve better procurement contract compliance; improve spending visibility, lower procurement transaction costs; and exert more control on spending management (Gupta 2007). Aberdeen's research analyst, Amit Gupta, has stated: "The procurement department is no longer just a transaction center for placing orders, but can also be a source of competitive advantage by acting as an information hub supporting business planning and decision-making. There is more to an e-procurement solution than cost savings; it is now a tool that removes manual error-prone repetitive tasks and promotes compliance with business controls allowing procurement resources to focus on more strategic tasks" (Selko 2007).

In this context, computer science researchers have made a number of notable efforts to develop agent-based systems that support electronic procurement with different structures and supporting technical approaches to enable solutions to the problem of winner determination, while reflecting buyer and seller constraints and preferences. An outstanding example of this kind of research is iBundler, which is described in Cerquides et al. (2007), Giovannucci et al. (2004, 2008) and Rodriguez-Aguilar et al. (2003). The authors describe their intelligent system as an agent-based negotiation service for buying agents and as a winner determination service for reverse combinatorial auctions with constraints on the attributes of individual items and multiple items in bundles. Another well-known proposed system is iAuctionMaker by Reyes-Moro and

* Corresponding author.
E-mail addresses: huanghe@cqu.edu.cn (H. Huang), rkauffman@asu.edu (R.J. Kauffman), xuhongyan@cqu.edu.cn (H. Xu), zhaol@oldwestbury.edu (L. Zhao).

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Rodriguez-Aguilar (2005), who developed and analyzed its performance. This second proposed system supports the work of an auctioneer who wishes to separate a superset of auction demand items into "promising bundles" that are likely to be more easily bid upon by suppliers who can deliver them in a competitive procurement market. The authors' approach involves the capture and encoding of expert knowledge from sourcing specialists, as a basis for creating algorithms that optimize buyer satisfaction with the supplied bundles based on multiattribute utility theory.[1]

Davenport and Kalagnanam (2002) point out that the procurement of direct inputs that are used in the manufacturing of a firm's primary products represent as much as 90% of its procurement spending. This dollar volume is large, and such procurement transactions occur with a high frequency. In their work at a large food manufacturing company, the authors note: "As a result there is considerable room for negotiations. However, a fundamental concern in such sourcing decisions is related to the reliability of suppliers, since defaulting suppliers might have considerable impact on the firm's ability to satisfy demand obligations. As a result, these negotiations are generally confined to a restricted number of pre-certified suppliers having established relationships with the company" (Davenport and Kalagnanam 2002, p. 27).

Early procurement auction models in economics tended to focus on the price of goods with fixed-quality bidding or quality-price pair bidding. Rothkopf and Whinston (2007) have noted that procurement auctions that are entirely based on non-negotiable supply quality and prices are not sufficient. If quality is not observable, or the buyer's profit based on the supplier's effort to deliver a quality product cannot be measured easily, then a buyer will benefit from offering an incentive contract to the supplier to compensate and stimulate effort so the transaction will yield greater value (Laffont and Tirole 1993).[2] Informational asymmetries naturally arise between buyers and sellers, when sellers have private information that cannot easily be obtained by buyers about what they are selling. This makes it difficult for them to agree upon a fair price for exchange (Akerlof 1970), which creates a need for minimum standards to be established in different settings (Leland 1979).

The present article is motivated by the business problem that arises in practical situations related to procurement, where the buyer initiates an auction for goods or services with a specific quality requirement, and solicits suppliers, who act as bidders. When a winning supplier emerges, the buyer may choose to either negotiate with the supplier to ensure an appropriate level of quality and price, or accept the auction price without negotiation.[3] In either case, because of moral hazard and adverse selection that may occur in the auction setting (Rothkopf and Whinston 2007), the buyer will benefit from being able to establish *incentives* to encourage an acceptable outcome and prevent an inappropriate level of effort on the part of the supplier to deliver quality goods or services (Bajari and Tadelis 2001). In practice, some sort of *bonus payment* to the supplier making more effort to deliver a quality product or service to the buyer and transaction completion is quite attractive (Parkes and Kalagnanam 2005).[4]

For example, many firms in China hire meal preparation service suppliers to prepare lunchboxes and dinners for their employees. Usually, the firms will invite bids from several suppliers and then negotiate with one supplier or just a few candidates, and set a monthly bonus for the final supplier, based on its performance. Performance can be assessed in various ways. For example, it might be proposed that a bonus be transferred to the supplier only if some fixed percentage of total employees (say 85%) rates the lunchbox service as "satisfactory." Another possibility is that evaluative scores on the service from the employees are all above some fixed level (say 80 out of 100 points). It might be hard to pre-specify employee satisfaction in the auction phase, however, thereafter the employees' satisfaction with the service will become common knowledge, and this should play an important role in supporting the two parties' decision about whether a bonus should be given. The business problem arises because procurement managers and their supplier still lack sufficiently refined knowledge to fully understand how the inner workings of quality effort bonuses, the procurement auction mechanism and the negotiation process are interrelated in the creation of supply chain surplus.

In this research, we will address this issue by analyzing two proposed procurement mechanisms involving economic exchange. We will focus on a setting in which the buyer chooses a winning supplier in a modified second-price sealed-bid auction, which hosts suppliers who make bids on delivering goods or services that meet a specific requirement for quality. When this is the case, there are two different possibilities. One possibility is that the buyer will buy the goods or services from the winning supplier at an appropriate and pre-determined level of quality, and a price for this supply will be established in auction. A second possibility is that the buyer may decide to negotiate with the winning supplier to obtain goods or services at a negotiated level of quality at a mutually agreeable price. In both cases, the buyer offers the supplier an effort bonus to encourage the supplier to make an appropriate though unobservable effort to deliver the goods or services in order to satisfy the buyer demand for quality. The dimensions of quality that are required may be non-contractible, so that observing pre-transaction quality is difficult or costly.

Our goal in this research is to provide more refined theoretical knowledge to support managerial decision-making for e-procurement mechanism selection. This will permit us to establish a clearer understanding of the quantitative relationship among the bid price in the procurement auction, the post-procurement auction negotiation quality and price, and the size of the bonus that is needed to engender the right effort level on the part of the supplier to deliver what the buyer wants. It will also allow us to recommend to the buyer how to implement an optimal strategy

[1] Generally speaking, commercial e-procurement auctions have been difficult to support technologically. Some examples of current commercial systems include: United States National Institute of Standards and Technology grant winner CombineNet (http://combinenet.com) (*BusinessWire* 2002); iSOCO's, especially iQuote (http://www.isoco.com) whose predecessor, Quotes, is discussed in depth by Cerquides et al. (2007) and Reyes-Moro et al. (2003); Hedgehog (http://www.hedgehog.com); and Avotis (http://www.avotis.com). See Appendix A for additional details.

[2] The term *verifiable quality* is widely used in the contract theory literature, however, to make our writing more accessible for the IS and e-commerce audience, we will refer to it as *observable quality* in this article. Similarly, we will refer to *unobservable quality*, when the buyer cannot ascertain quality in advance of the shipment, receipt and inspection of the supplies received (Laffont and Tirole 1993, Kessler and Lulfesmann 2004, Dmitri et al. 2006). Observed and unobserved quality are also often used to distinguish product quality expectations and delivered product quality in software engineering, where there is an interest in simultaneous managing cost and quality, while avoiding the deployment of software with defects (Austin 2001, Banker and Kemerer 1992, Westland 2004).

[3] For a fuller review of the literature on bilateral negotiation and bargaining from the computer science perspective, the interested reader should see Li et al. (2003).

[4] The literature on procurement frequently uses the terms *bonus* and *bonus payment* to indicate some sort of transfer payment from the buyer to participating suppliers in supply chain procurement operations to encourage truthful participation (Bigoni et al. 2010, Mishra and Parkes 2007, Mishra and Veeramani 2007). The software engineering economics literature also uses similar language related to performance for software contracts and software development projects (Austin 2001, Hitt et al. 1999), which reflects application of the terms in employee and manager compensation. Other research on procurement, firm relationships and supply chain management focuses on *subsidies* that support interorganizational technology adoption and supplier participation (Riggins et al. 1994, Wang and Seidmann 1995), as well as the sharing of inventory holding costs (Nagarajan and Rajagopalan 2008). The term *transfer pricing* is more common in the resource allocation literature, for example, related to congestible networks (Westland 1991, Mackie-Mason and Varian 1995). All three of these terms are used to indicate some sort of exchange of value between different kinds of participants in contracts and interfirm relationships.