Trust in Procurement Interactions

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Abstract. When complex procurement projects are conducted, it is often not possible to write complete contracts. As a consequence, the relationship between buyer and supplier is important for the success of the project. In this paper we investigate the claim that auctions in procurement can be detrimental for the buyer–supplier relationship, which is in line with the observation that reverse auctions are less frequently conducted if projects are complex. A poor relationship can result in a decrease in trust on the part of the buyer during the sourcing process and an increase in the supplier's opportunistic behavior following sourcing. We consider a setting in which the winning supplier decides on the level of quality to provide to the buyer, and we compare a standard reverse auction and a buyer-determined reverse auction, both analytically and in the laboratory. We find that the buyer-determined reverse auction can perform better than the standard reverse auction from both the buyer's and the suppliers' perspective. In a buyer-determined reverse auction, it may be optimal for the buyer to select the supplier who submitted a higher bid, which may in turn induce this supplier to deliver higher quality. Standard auctions, however, yield lower prices but reduce cooperation. The degree of trust, as reflected by a larger number of transactions and a higher average efficiency of trade, is significantly higher in buyer-determined reverse auctions. Theoretical reasoning based on other-regarding preferences organizes our data well.

1. Introduction

The use of reverse auctions to purchase goods and services has been steadily growing since mid-1990s (Elmaghraby 2007). Carter et al. (2004) report that in 2003, a conservative estimate of the annual volume of these auctions was $400 billion in the United States alone, and that 85% of firms surveyed in a large-scale study consider using reverse auctions for procurement. A study by Beall et al. (2003) projected the annual growth rate of 20%, and Verespej (2004) estimates realized cost savings attributed to auctions to be in the 20%–40% range in a diverse set of industries. In addition to cost savings, auctions provide other benefits, such as lowered transaction times (Shugan 2005), expansion of the supply base (Beall et al. 2003), price visibility, and information transparency (Haruvy and Katok 2013).

The major disadvantage of auctions, cited by researchers and practitioners alike, is that they damage *the relationship between buyers and suppliers*. Emiliani and Stec (2005), for example, argue that because auctions erode suppliers' profit margins, they encourage unethical behavior designed to cut costs at the buyer's expense. So although effective at lowering prices in the short term, by using competition, auctions may be eroding trust in the long term, by removing incentives to share information (Kim and Netessine 2013) and invest in process improvement.

As an illustration of how auctions, through their emphasis on competition, *erode trust*, Liker and Choi (2004) discuss the contrast between the U.S. and Japanese automakers in their approach to relationships with suppliers. All car makers heavily rely on their suppliers because the modern method of manufacturing automobiles requires multiple sourced components to be integrated and assembled. Kallstrom (2015) reports that automobile Tier 1 and Tier 2 suppliers were responsible for over 80% of added value in 2015—the proportion has been steadily rising from close to 56% in 1985. The approach U.S. automakers take is to award contracts based strictly on price and through the threat of using auctions to re-source, erode suppliers' profit margins, and capture most of the savings as a result of innovation. Stallkamp (2005, p. 19) calls this approach "adversarial commerce" and attributes the deterioration of quality that General Motors experienced in early 1990s to the low level of trust that adversarial commerce precipitated.

It appears that a lack of collaboration with suppliers is not unique to U.S. automakers. In late 2016, German car maker Volkswagen (VW) "stopped, or partially stopped, work at six of its biggest assembly plants, affecting a total of 28,000 workers, due to a contract dispute with two component suppliers, ES-Automobil Guss GmbH and Car Trim GmbH" (Smith 2016). The cause of the dispute was the effort by VW to cut approximately 1 billion euros in costs, following the infamous VW emission scandal that came to light early in 2016. VW was attempting to implement these cost savings by pressuring suppliers, but several suppliers responded by suspending deliveries, leading to work interruptions and costing VW over 100 million euros.

In contrast to American and European automakers, their Japanese counterparts, such as Honda and Toyota, have traditionally treated suppliers with more loyalty. These automakers form longer-term cooperative relationships with suppliers and incentivize them to improve their processes, rewarding good performance by increasing the volume of orders. Japanese automakers do not, as a rule, squeeze their suppliers on price but instead achieve cost savings without sacrificing quality by providing inducements to innovate (Stallkamp 2005).

Tension between competition and cooperation is not limited to the automobile industry. The work by Bajari et al. (2009, 2014) deals with this topic in the construction industry. These papers report on empirical evidence that reverse auctions perform worse than more flexible mechanisms, for the procurement of complex construction projects. Similar to the setting we investigate in this paper, nonstandard construction projects often require ex post adjustments that are not included in the initial contract, and if the supplier does not cooperate, these adjustments can be costly to the buyer. Bajari et al. (2009) report that in the private sector, only 18% of the construction projects are awarded using reverse auctions, and auctions are less likely to be used for complex or nonstandard projects. In the public procurement, however, government regulations require the use of reverse auctions for most construction projects. These public procurement auctions, according to Bajari et al. (2014), result in average cost overruns of 5.8%.

In procurement, the point at which the trade takes place (the buyer awards the contract to a supplier) is the beginning, rather than the end of the relationship between the buyer and the supplier. We explicitly consider a setting in which the contract price is negotiated and the contract is awarded first, and the supplier decides on the quality she delivers afterward. Quality is costly for the supplier, but it generates disproportional value to the buyer, so high quality is efficient. However, for high quality to be achieved, the buyer has to *trust* the supplier to deliver it voluntarily, because the contract does not specify quality level.[1] Consequently, to sustain an efficient outcome requires not only the trust of the buyer but also the *trustworthiness* of the supplier. The buyer, then, faces a predicament, because on the one hand, a reverse auction designed to automatically award the contract to the lowest bidder will deliver a low price, but in the absence of trust, the quality the supplier will deliver after the auction is likely to also be low. On the other hand, the buyer may not commit to awarding the contract to the lowest bidder. Such *buyer-determined reverse auction* (BDRA) may result in a higher price, but the buyer's willingness to trade at a high price may induce supplier's trustworthiness, resulting in higher quality delivered after the auction.

In this paper, we investigate how the winner determination rule of procurement auctions influences the amount of cooperation between the buyer and the supplier, when the supply contract is incomplete. Specifically, we consider the effect of the procurement mechanism on the buyer's willingness to trade at high prices (trust) and the supplier's willingness to voluntarily provide costly quality that benefits the buyer and is not specified in the contract (trustworthiness). In our setting, two potential suppliers compete for a contract by submitting sealed bids (or offers). In the binding auction, the buyer can either accept the lowest bid or refuse to trade, whereas in the BDRA, the buyer also has the option to accept a higher bid. If the buyer accepts an offer, the selected supplier decides on the quality of the product.

Higher quality is more valuable to the buyer but is also more costly to the supplier. Standard preferences imply that, regardless of the winner determination rule, the auction winner will deliver the lowest quality. Understanding this, the buyer will award the contract only to the lowest bidder, and therefore, the two suppliers will compete the price down to their cost of delivering the lowest quality. We develop a stylized analytical model of the interaction between the buyer and the auction winner that captures their social preferences, and we show that collaborative behavior is more likely under the BDRA mechanism than it is under the binding auction. The model predicts higher prices and higher quality levels under the BDRA and shows that it can be worthwhile for the buyer to choose the higher, rather than the lower, bid in the BDRA. We test the model predictions in a controlled laboratory setting with human subjects and find that the data support the main predictions of the model.

The interest in issues involving social preferences and trust has been growing in the operations management. A seminal paper by Cui et al. (2007) on the role of fairness in contracting shows that fairness concerns can lead to channel coordination under the wholesale price contract. This research emphasizes that the notion of distributive fairness is important in commercial relationships and is not limited to individuals. In a related work, Cui and Mallucci (2016) use analytical modeling and laboratory experiments to investigate how fairness

affects distribution channels. They find that pricing decisions they observe can be explained by fairness motives.

Another stream of literature related to our work deals with trust. Özer et al. (2011) investigate the role of trust and trustworthiness in sharing forecasting information. They observe both trust and trustworthiness and use a model that includes disutility of lying to organize their empirical findings. In a related paper, Özer et al. (2014) replicate the results in China and further analyze the effect of cultural differences on trust and trustworthiness. The notion that mechanisms can have an effect on the level of trust and trustworthiness is similar to ours. Özer et al. (2018) explore this idea in the retailing context.

Most papers that analyze BDRA assume that suppliers compete on price, and the quality is exogenous. Engelbrecht-Wiggans et al. (2007) compare a binding (price-based) and a nonbinding (BDRA) mechanism and show that, theoretically, BDRAs are more profitable for the buyer if the correlation between costs and quality is high and there is a sufficient number of competitors. They also provide experimental evidence for their predictions. Haruvy and Katok (2013) also investigate a setting with exogenous quality and study the effect of price visibility during the auction (open versus sealed-bid) and information transparency (whether bidders know the exogenous quality level of the competitors). They find that the buyer benefits by providing less information to the suppliers. In Fugger et al. (2016) we stress-test the idea that less information is better for the buyer by analyzing a setting in which suppliers are uncertain about their own quality level. Suppliers bid in open-bid reverse auctions that are either binding or buyer determined. In such a setting, the buyer faces a trade-off because binding auctions result in low prices but the winning supplier may not provide the best fit in terms of the quality. By contrast, BDRAs allow the buyer to choose the supplier with the best fit, but they can also enable tacit collusion among suppliers, causing higher prices.[2] We contribute to this literature by studying a setting in which quality is endogenous, and social preferences are included in the model.

A closely related topic is the optimal contract design for complex procurement projects. Kim and Netessine (2013) examine the influence of the opportunity of collaborative cost reductions on the optimal contract design in the presence of asymmetric information. They show that screening contracts may not be optimal. If the collaborative cost reductions are large or the demand variability is low, the buyer prefers a contract in which she commits to a fixed margin over the expected costs. The reasoning is that a supplier will only invest in collaborative cost reductions if he can claim part of the rewards.

Brosig-Koch and Heinrich (2012), like us, consider an auction setting with endogenous quality. Unlike us, they analyze the role of reputation in procurement auctions. In an experimental study, they find that price-based auctions are less profitable for buyers than are BDRAs. In BDRAs, buyers are able to base their selection on suppliers' past performance. A structural difference between our setting and that of Brosig-Koch and Heinrich (2012) is that their setting cannot be used to measure trust because buyers do not have the option to refuse trade, and all trades are guaranteed to be profitable for the buyers. In our setting, however, buyers are at risk of making losses and are free to refuse trade. This specification gives us the opportunity to analyze the influence of the procurement mechanism on buyers' trust.

Our work is also related to experimental literature analyzing the influence of social norms on competition. The starting point of this stream of literature is the *fair wage-effort* hypothesis, which states that workers receiving a larger payment exert more effort. Fehr et al. (1993) were the first to provide experimental evidence for a positive correlation between a worker's wage and the effort the worker exerts. Similar to us, Fehr et al. (1993) examine a setting in which the effort (which has the same role as quality in our setting) cannot be contracted. Unlike us, however, Fehr et al. (1993) consider a situation in a labor market frame in which buyers (employers) post prices (wages) and in which there are both many buyers (employer) and many suppliers (workers). They observe that prices are substantially higher than the market clearing price and that suppliers provide higher than minimum effort. For an overview of this extensive literature, we refer interested readers to Fehr and Schmidt (2006) and the references therein.

In the next section, we present our analytical results, starting with the model setup, and then analyze the setting with standard preferences as well as the setting with social preferences. In Section 3, we formulate research hypotheses implied by our analytical model and describe the experiment that we designed to test these hypotheses. In Section 4, we report the results of our experiments. We conclude the paper in Section 5 by summarizing our results, discussing alternative explanations, and offering managerial implications for designing and implementing competitive procurement mechanisms.

2. Model Setup

We model a setting with a single buyer and multiple potential suppliers $i \in \{1, \ldots, n\}$. The buyer (she) wants to select one supplier (he) to fulfill a contract, and the value to the buyer v from this contract depends on the level of *quality* $q \in \{q^1, \ldots, q^m\} = \mathcal{Q}$ (with $m \geq 3$) that the selected supplier will deliver. The selected supplier's cost c depends on the level of quality provision $c(q^j)$. We assume that cost is strictly increasing in quality (i.e., $c(q') > c(q'')$ for all $q' > q''$) and that the buyer's valuation is always larger than the supplier's cost (i.e., $v(q) > c(q)$

for all q). Both cost and quality are common knowledge. We also assume that welfare increases in quality (i.e., $v(q^j) - c(q^j) > v(q^k) - c(q^k)$ for all $j > k$). The relative efficiency gains from providing higher quality are decreasing (i.e., $[v(q^{j+1}) - v(q^j)]/[c(q^{j+1}) - c(q^j)] < [v(q^j) - v(q^{j-1})]/[c(q^j) - c(q^{j-1})]$ for all $1 < j < m$). The motivation behind this assumption is that suppliers have different options to increase the value of the good for the buyer and will first choose those that are least expensive. Finally, we assume that it is impossible to write a contract contingent on quality. This may be, for example, because the buyer's valuation for quality is a function of unobservable costly effort by the supplier.

We consider two mechanisms for the procurement stage: The first is the binding price-based first-price sealed-bid reverse auction (that we label as *Auction*), in which the buyer must award the contract to the supplier who submitted the lowest price bid. The second mechanism is the buyer-determined sealed-bid reverse auction (that we label *BDRA*), in which the buyer is allowed to select any winning supplier. Suppliers can place bids from the discrete price grid $\mathcal{G} = \{c(q^1), c(q^1) + \Delta, \ldots, v(q^m) - \Delta, v(q^m)\}$, and Δ is assumed to be small. In both mechanisms, the buyer has the option to refuse to trade, in which case all parties earn nothing. If the buyer accepts one of the bids, the profit of the buyer is given by the difference between her valuation $v(q^j)$ for the quality level q^j provided by the selected supplier and his bid b_i. The selected supplier's profit is given by the difference between his bid b_i and his cost $c(q^j)$ of providing quality q^j. All other suppliers earn nothing.

The sequence of events for both procurement mechanisms is as follows:

1. Suppliers simultaneously submit bids $b_i \in \mathcal{G}$. Let b_i denote the bid of bidder i, and let $\mathbf{b} = (b_1, \ldots, b_n)$ denote the vector containing all bids. Furthermore, let b^k denote the kth lowest bid. If two or more suppliers placed the same bid, ties are broken randomly.

2. We use one of two mechanisms:

(a) Auction: The buyer observes all bids $\mathbf{b}$ and decides whether to accept the lowest bid b^1 or refuse to trade. Let $\mathcal{A}^{Auction} = \{a^0, a^1\}$ be the action set of the buyer, where a^0 corresponds to refusing trade and a^1 to accepting the lowest bid b^1.

(b) BDRA: The buyer observes all bids $\mathbf{b}$ and decides whether to accept one of the bids or refuse to trade. Let $\mathcal{A}^{BDRA} = \{a^0, a^1, \ldots, a^n\}$ denote the action set of the buyer, where a^0 corresponds to refusing trade and a^k to accepting the kth lowest bid b^k.

3. Suppliers observe all bids $\mathbf{b}$ and the buyer's acceptance decision. If the buyer accepted a bid, the selected supplier decides on the quality $q \in \mathcal{Q}$ to provide.

A strategy of a supplier consists of a bid $b_i \in \mathcal{G}$ and a mapping from bids $\mathbf{b}$ to a quality choice $q \in \mathcal{Q}$. A strategy of a buyer is a mapping from a bid vector $\mathbf{b}$ to an acceptance decision.

2.1. Standard Model

If we assume that all individuals always seek to maximize their profit, the procurement interaction can be modeled as an extensive-form game with complete information. The game tree is depicted in Figure 1. Applying backward induction, we can identify the subgame perfect Nash equilibria of the game.

Proposition 1. *In each subgame perfect equilibrium of the Auction and the BDRA, the price is equal to c^1 or equal to $c^1 + \Delta$, the minimum quality q^1 is provided, and trade takes place.*

Proof. In the delivery stage, the selected supplier chooses the quality level that maximizes his profit (i.e., $\max_{q \in \mathcal{Q}} b_i - c(q)$). Because costs are strictly increasing in quality, he will always provide the lowest possible quality level q^1. In the procurement stage, the buyer anticipates that she will receive lowest quality q^1 whenever she accepts a bid. Hence, she will refuse to trade (a^0) if all bids are larger than $v(q^1)$. If the lowest bid b^1 is smaller than or equal to $v(q^1)$, she will accept this bid (a^1). In the bidding stage, two equilibrium outcomes are possible. Either all suppliers place a bid of $c(q^1) + \Delta$ or at least two suppliers place a bid of $c(q^1)$. If all suppliers bid $c(q^1) + \Delta$, each supplier expects a profit of Δ/n, and any deviation would result in zero profit. If at least two suppliers bid $c(q^1)$, each supplier makes a profit of zero, and no supplier has an incentive to deviate. Equilibrium prices larger $c(q^1) + \Delta$ are not possible because suppliers would have an incentive to undercut. □

In addition to these subgame perfect Nash equilibria, other Nash equilibria exist. In some of them no trade takes place; others have equilibrium prices larger than $c(q^1) + \Delta$. However, all equilibria have in common that the buyer will never accept a bid larger than $v(q^1)$ and that no supplier will provide more than minimum quality q^1.

2.2. A Model with Social Preferences

In contrast to the assumption that all individuals only seek to maximize their profits, many observations in experimental economics suggest that some individuals are not solely motivated by profit maximization but are also affected by fairness considerations. In this section we analyze how the predictions for the procurement interactions change when we apply a model that incorporates inequity aversion as suggested by Fehr and Schmidt (1999) or Bolton and Ockenfels (2000).

Similar to a profit maximizer, an inequity-averse individual benefits from his or her own monetary payoff. However, in addition to this benefit, the individual suffers a utility loss from a difference between his or her

Figure 1. Game Trees
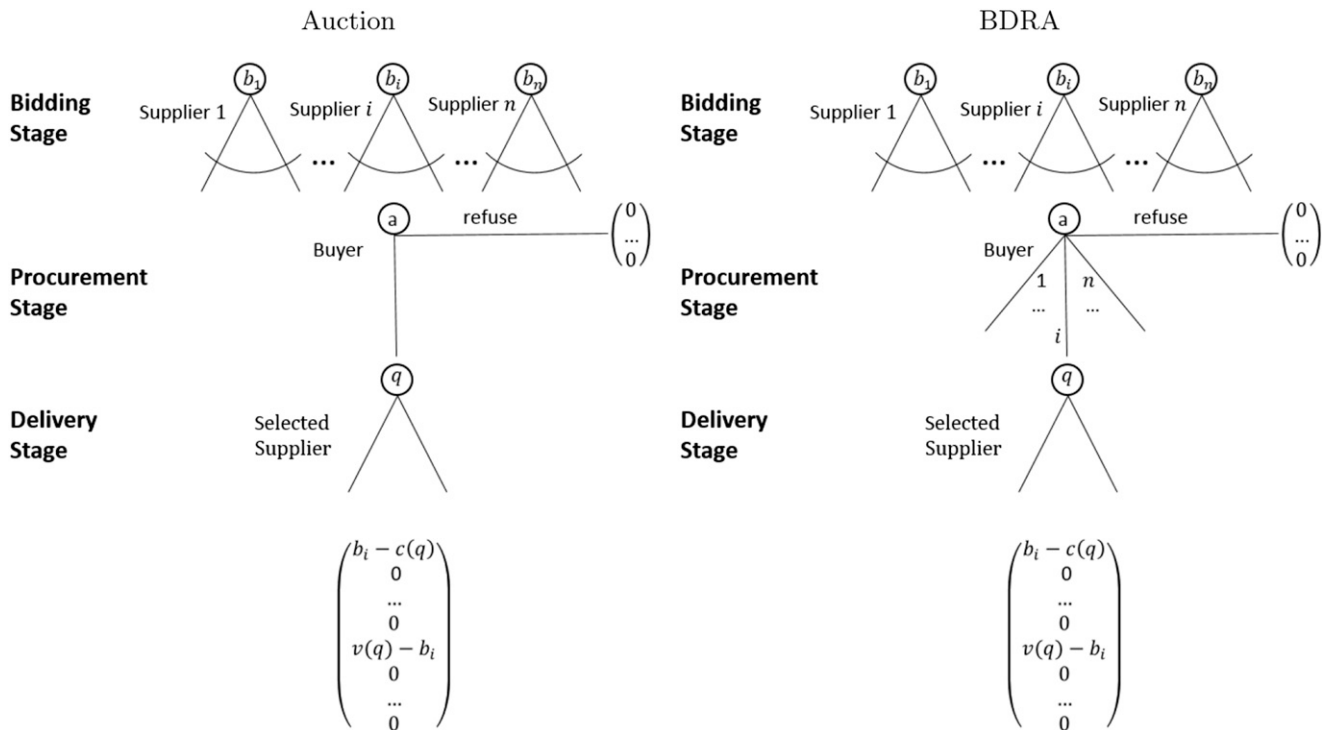
Notes. This is a sequential game. Suppliers $\{1, \ldots, n\}$ move first; each supplier i submits a bid b_i. In the Auction, the buyer can then either select the lowest bidder and pay his bid b_i or refuse to trade. In the BDRA, the buyer can select any of the bidders and pay his bid b_i or refuse to trade. The winner then selects quality q, incurs the cost $c(q)$, and earns profit of $b_i - c(q)$. The buyer earns the profit of $v(q) - b_i$. All other suppliers earn nothing.

own monetary payoff and that of the members of the reference group. Fehr and Schmidt (1999) represent the utility of an inequity averse individual i as follows:

$$
x_i - \alpha \cdot \frac{1}{n-1} \cdot \sum_{k \neq i} \max[x_k - x_i, 0] - \beta \cdot \frac{1}{n-1}
$$
$$
\cdot \sum_{k \neq i} \max[x_i - x_k, 0]. \tag{1}
$$

Here, x_i denotes the monetary payoff of individual i and x_k the monetary payoff of individual k, who is a member of i's reference group, which consists of n individuals. The α expresses how much an individual suffers from *disadvantageous inequality*, and β reflects how much he or she suffers from *advantageous inequality* with $\alpha, \beta \geq 0$.[3]

We assume that the relevant reference group consists of the buyer and the selected supplier. One might argue that suppliers compete anonymously in the bidding stage and that buyer's selection initiates a fundamental transformation in the sense of Williamson (1985). For example, Hart and Moore (2008) make an argument along these lines.[4] From (1) it follows that if supplier i submits bid b_i and is selected, then this supplier's utility is

$$
u(q, b_i) = b_i - c(q) - \alpha \cdot \max[v(q) + c(q) - 2b_i, 0] - \beta
$$
$$
\cdot \max[2b_i - v(q) - c(q), 0]. \tag{2}
$$

The utility of the buyer depending on the accepted bid b_i and the quality q provided by the selected supplier is given by

$$
w(q, b_i) = v(q) - b_i - \alpha \cdot \max[2b_i - v(q) - c(q), 0] - \beta
$$
$$
\cdot \max[v(q) + c(q) - 2b_i, 0]. \tag{3}
$$

We analyze the influence of inequity aversion in a setting in which participants are homogeneous. An extension of the analysis, in which we apply a quantal response equilibrium (QRE) concept to examine how heterogeneity among individuals or mistakes affect results, can be found in the appendix. If buyers and suppliers are inequity averse but homogeneous, then our setting is modeled as an extensive-form game with complete information. We use backward induction to identify subgame perfect Nash equilibria. In the delivery stage, the selected supplier maximizes his utility by deciding on the quality level $q \in \mathcal{Q}$. Because of his inequity aversion, the optimal quality level depends on the accepted bid b_i, as illustrated in Figure 2(a).

Before we derive the selected supplier's optimal quality choice, we define the set of implementable quality levels $\mathcal{Q}^I \subset \mathcal{Q}$.

Figure 2. The Utilities of the Selected Supplier and the Buyer as a Function of the Accepted Bid b_i and the Level of Quality Provision q
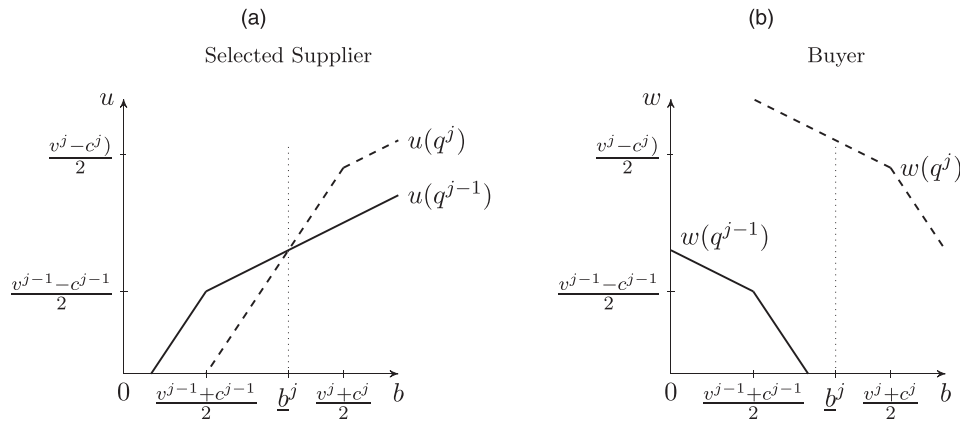
Notes. Displayed is the selected supplier's and the buyer's utility as a function of the price and the provided quality level. The slopes of the utility functions depend on the relative profits. For the selected supplier, the slope is $1 + 2\alpha$ if he earns less than the buyer and $1 - 2\beta$ if he earns more than the buyer. For the buyer, the slope is $2\beta - 1$ if she earns more than the selected supplier and $-2\alpha - 1$ if she earns less than the selected supplier. Furthermore, $\underline{b}^j$ denotes the price at which the selected supplier is indifferent between the provision of quality level $j - 1$ and j.

A quality level $q^j \in \mathcal{Q}$ is called *implementable* if there exists a price for which the selected supplier prefers to provide this quality level over all other quality levels. The set of all implementable quality levels is denoted by $\mathcal{Q}^I = \{q^1, \ldots, q^r\} \subset \mathcal{Q} = \{q^1, \ldots, q^m\}$.

Lemma 1. *A quality level $q^j \in \mathcal{Q}$ is implementable given β if*
(1) *$j = 1$ or*
(2) *$j \neq 1$ and $\beta \geq \frac{c(q^j) - c(q^{j-1})}{v(q^j) - v(q^{j-1}) + c(q^j) - c(q^{j-1})} := \frac{\Delta^j c}{\Delta^j q + \Delta^j c}$.*

For the remainder of the analysis, we will assume that at least quality level q^2 is implementable. If this was not the case, there would only exist a low-quality equilibrium in both procurement mechanisms. Because relative efficiency gains from providing higher quality are decreasing, quality level q^{j-1} is implementable if quality level q^j is implementable.

For $q^j \in \mathcal{Q}^I$ with $j > 1$, the selected supplier will strictly prefer providing quality level q^j over all lower quality levels whenever the price is larger than

$$
\frac{\alpha \cdot [v(q^j) + c(q^j)] + \beta \cdot [v(q^{j-1}) + c(q^{j-1})] + [c(q^j) - c(q^{j-1})]}{2 \cdot (\alpha + \beta)}
$$
$$
\in \left[\frac{v(q^{j-1}) + c(q^{j-1})}{2}, \frac{v(q^j) + c(q^j)}{2} \right].
$$

Let $\underline{b}^1 \leq [v(q^1) + c(q^1)]/2$ denote the lowest acceptable bid for a supplier, and let $\underline{b}^j \in \mathcal{G}$ with $j > 1$ denote the lowest bid for which the selected supplier prefers to provide quality level q^j over q^{j-1}.[5]

The selected supplier's optimal quality choice as a function of the price is uniquely given by

$$
q^*(b) = \begin{cases} q^1 & \text{if } \underline{b}^1 \leq b < \underline{b}^2, \\ q^k & \text{if } \underline{b}^k \leq b < \underline{b}^{k+1} \text{ for } k \in (2, r-1), \\ q^r & \text{if } \underline{b}^r \leq b. \end{cases} \quad (4)
$$

It is easy to see that the quality level is (weakly) increasing in the accepted bid. This is also illustrated in Figure 2(a).

Proposition 2. *For prices larger than $\underline{b}^j$ with $j > 1$, suppliers strictly prefer providing quality level q^j over all lower quality levels.*

Proof. Follows directly from (2). □

The specification of the supplier's utility function also implies that shifting all valuations from $v(q)$ to $v(q) + \phi$ for all $q \in \mathcal{Q}$ with $\phi > 0$ does not affect the implementability of the different quality levels as the relative efficiency gains stay constant. However, the prices necessary to implement a certain quality level are increasing in ϕ.

Proposition 3. *An upward shift of the valuations from $v(q)$ to $v(q) + \phi$ does not affect the implementability of quality levels but increases the prices that are necessary to implement a certain quality level q^j with $j > 1$ for $\phi > 0$.*

Proof. Follows directly from (2). □

In the procurement stage, the buyer is aware of the connection between the accepted bid b and the quality level q^j she will receive.

An illustration of the buyer's preferences is presented in Figure 2(b).

For $\beta < 1/2$,[6] the buyer's utility given a quality level q^j is strictly decreasing in the accepted bid. This implies that the bids $\underline{b}^j$ are a local maximizer of the buyer's utility function, because all prices below $\underline{b}^j$ result in a lower quality level. We denote the set that consists of these bids as $\mathcal{B}_{\beta < 1/2} = \{\underline{b}^1, \underline{b}^2, \ldots, \underline{b}^r\}$. Furthermore, we denote the global maximizer of the buyer's utility as $b^*_{\beta < 1/2} \in \mathcal{B}_{\beta < 1/2}$.

For $\beta > 1/2$, the inequity motive dominates the profit maximization incentive. Hence, the buyer prefers

a price that implements an equal split over all other possible prices that implement the same quality level. In this case, the global maximizer of the buyer's utility $b^*_{\beta > 1/2}$ lies in the interval $\left[\frac{v(q^m)+c(q^m)}{2} - \Delta, \frac{v(q^m)+c(q^m)}{2} + \Delta \right]$ and results in the highest quality level r.[7]

Auction. In the Auction, the buyer can choose between accepting the lowest bid and refusing to trade. Hence, she will accept the lowest bid b^1 whenever this is associated with a positive utility $w(q^*(b^1), b^1) \geq 0$ and refuse to trade if it is not. A supplier can only be selected in an Auction if he placed the lowest bid among his competitors. As a consequence, a low-price equilibrium in which all suppliers bid $\underline{b}^1$ and provide quality q^1 always exists in an Auction.[8]

Proposition 4. (a) *In each Auction, there exists a subgame perfect low-price equilibrium in which all suppliers bid $\underline{b}^1$, the buyer accepts, and the selected supplier provides the lowest quality level q^1.*

(b) *In each subgame perfect high-price equilibrium of an Auction, all suppliers place the same bid $\hat{b} \in \mathcal{B}_{\beta < 1/2} \setminus \underline{b}^1$, and the buyer accepts. The bid $\hat{b} \in \mathcal{B}_{\beta < 1/2} \setminus \underline{b}^1$ can only be an equilibrium bid if $w\left(q^*(\hat{b} - \Delta), \hat{b} - \Delta\right) < 0$.*

Proof.

(a) Suppose that all suppliers in an Auction bid $\underline{b}^1$. Because $\underline{b}^1 < [v(q^1) + c(q^1)]/2$, the buyer expects strictly positive utility from accepting and always accepts.

The selected supplier's utility $w(q^1, \underline{b}^1)$ is (weakly) positive. From $\underline{b}^1 < [v(q^1) + c(q^1)]/2$ also follows that the selected supplier prefers to provide quality q^1. Suppliers do not have an incentive to place a lower bid, because $\underline{b}^1$ is the lowest acceptable bid (i.e., the lowest bid resulting in a positive utility in case of selection), and all smaller bids are associated with a negative utility in case of selection. A deviation to a higher bid is not profitable because such a bid would never be selected; that is, it is associated with an expected utility of zero. Hence, neither the buyer nor suppliers have an incentive to deviate, and the low-price low-quality equilibrium exists.

(b) First, suppose there was an equilibrium without trade. Then the buyer and all suppliers make zero profits. Subgame perfection implies that the buyer only rejects if all bids are larger than $\frac{v(q^1)+c(q^1)}{2}$. Because $v(q^1) > c(q^1)$, there exists a bid $b' \in \left(\underline{b}^1, \frac{v(q^1)+c(q^1)}{2} \right]$ such that both the buyer and the selected supplier prefer trading at a price b' over not trading at all. Second, for each bid $b > \underline{b}^1$, a supplier strictly prefers being the selected supplier over not being the selected supplier. Hence, there cannot be a subgame perfect high-price equilibrium in which not all suppliers place the same bid.

For bids $b'' \notin \mathcal{B}_{\beta < 1/2}$ that would be accepted by the buyer, there always exists a bid $b'' - \Delta$ that would also be accepted by the buyer. Because Δ is arbitrarily small, a supplier would have an incentive to deviate to $b'' - \Delta$. Therefore he would place the unique lowest bid, would increase his selection probability to 1, and would decrease his utility in case of selection only slightly. Only for bids $b \in \mathcal{B}_{\beta < 1/2}$ would this incentive need not exist. For these bids, $b - \Delta$ are associated with a lower quality level, which might imply that they are rejected by the buyer because $w(q^*(b - \Delta), b - \Delta) < 0$. The supplier then has no incentive to deviate by placing a slightly lower bid. □

Proposition 4 represents a necessary condition for the existence of a high-price equilibrium in an Auction. A further requirement for the existence of a high-price equilibrium is that no supplier has an incentive to place a (substantially) lower bid. For example, the larger the number of suppliers, the smaller the winning probability when pooling, and therefore, the stronger the incentive to deviate.[9]

BDRA. In a BDRA, the buyer can choose between all bids and can also refuse to trade. Therefore, she will accept the bid that is associated with the largest positive utility and refuse to trade if no bid that is associated with a positive utility was submitted. In contrast to an Auction, the buyer need not select the lowest bid in order to trade, which reduces the suppliers' incentives to undercut competitors. As a consequence, a low-price equilibrium need not exist.

Proposition 5. *If $\beta < 1/2$, all suppliers place the same bid from the set $\mathcal{B}_{\beta < 1/2}$, and trade takes place in each subgame perfect equilibrium of the BDRA. Furthermore, the equilibrium bid must be larger or equal than the buyer's globally preferred bid b^*. If $\beta > 1/2$, all suppliers bid $b^*_{\beta > 1/2}$, and trade takes place in the unique subgame perfect (high-price) equilibrium.*

Proof. Analogous to the Auction, there cannot be a high-price equilibrium in which no trade takes place or in which suppliers place different bids. We assume that suppliers are not indifferent between being selected and not being selected at a price of $\underline{b}^1$.

We start with the case of $\beta < 1/2$. Suppose there was a high-price equilibrium bid $b' \notin \mathcal{B}_{\beta < 1/2}$. Then there is also a bid $b' - \Delta$ that is strictly preferred by the buyer, and suppliers would have an incentive to deviate. Hence, there cannot be an equilibrium bid $b' \notin \mathcal{B}_{\beta < 1/2}$.

If $\hat{b}$ were smaller than the bid $b^*_{\beta < 1/2}$, which is the global maximizer of the buyer's utility, a supplier would have an incentive to bid $b^*_{\beta < 1/2}$ instead of $\hat{b}$. Because the buyer prefers this bid over all other bids, the deviating supplier would increase his selection probability and also his utility in case of selection.

If $\beta > 1/2$, the buyer's utility is maximized when accepting $b^*_{\beta > 1/2}$. Because of the same argument as before, there cannot be an equilibrium bid smaller than $b^*_{\beta > 1/2}$. An equilibrium bid larger than $b^*_{\beta > 1/2}$ is also not possible because suppliers would have an incentive to undercut slightly. □

From Proposition 5 it directly follows that a low-price equilibrium exists only if $\beta < 1/2$ and if at the same time $\underline{b}^1 = b^*_{\beta < 1/2}$ (i.e., if $\underline{b}^1$ is the buyer's globally preferred price).

The application of the social preference model shows that the Auction and the BDRA need not be outcome equivalent. Although a low-price equilibrium always exists in an Auction, it need not exist in a BDRA. One can also construct cases in which the BDRA has only a high-price equilibrium, whereas the Auction only has a low-price equilibrium. Put differently, the requirements for the existence of a high-price equilibrium are more restrictive in the Auction than in the BDRA.

3. Experimental Design and Hypotheses
3.1. Experimental Design and Protocol
In the laboratory experiment, we consider a setting in which one buyer faces two potential suppliers. The selected supplier can choose between seven quality levels. The second row of Table 1 indicates the costs associated with the seven quality levels in our experiment. The third and fourth rows of Table 1 display the two sets of buyer's values we used in our study. In the *High* value condition, the buyer's value from trade included an additional 100 ECUs (experimental currency units) compared with the *Low* value condition.[10] The schedule of suppliers' costs and the buyer's values was displayed on all decision screens.

The procurement stage of our study included either the Auction or the BDRA. Thus, our study features a 2×2 full factorial design that varies the buyer's value structure (high or low) and the procurement mechanism (Auction or BDRA).

Each of the four treatments included six independent cohorts, each cohort had nine human participants, three buyers and six suppliers, who were randomly matched in 30 procurement interactions. Each laboratory session was conducted with two cohorts (18 people) in the laboratory simultaneously. The buyer/supplier roles were fixed for the duration of the sessions, and the matching was random. In total, 216 human subjects participated in our study.

Each participant was randomly assigned to one of the four treatments. All experimental sessions were conducted in the Cologne Laboratory for Economic Research at the University of Cologne. Participants were recruited using the online recruitment system ORSEE (Online Recruitment System for Economic Experiments Greiner 2015), and earning money was the only incentive offered.

Upon arrival at the laboratory, the participants were seated at computer terminals. They were handed written instructions, and they read these on their own. When all participants had finished reading, and before the sessions started, we read the instructions aloud. This ensured that all participants had been informed of the rules of the game. Random matching was used, and there was no way for participants to identify one another. At the beginning of each round, the nine participants in a cohort were divided into three groups consisting of one buyer and two suppliers. The experimental interface was programmed using the z-Tree system (Fischbacher 2007). At the end of the sessions, we computed cash earnings for each participant by multiplying the total earnings from all rounds by a predetermined exchange rate of 100 ECUs per euro and adding it to a show-up fee of 4 euros. Participants were paid their earnings in cash in private at the end of the session. Sessions lasted approximately 60 minutes, and participants earned an average of 18.91 euros.

3.2. Hypotheses
Table 2 presents an overview of our predictions and hypotheses. Hypothesis 1 is based on standard theory and implies that buyers and sellers will earn the same profit under the two mechanisms and, moreover, that sellers will compete away all their profit, earning nearly zero, whereas buyers will earn about $v(q^1) - c(q^1)$ (i.e., 4 or 5 in the low treatment and 104 or 105 in the high treatment). Additionally, the hypothesis implies that the efficiency under both mechanisms will be low, and buyers will not accept any offer $b_i > v(q^1)$ under either procurement mechanism, because such an offer will result in a loss.

Hypothesis 1 will be rejected by the data, and therefore we state hypotheses based on our model of social preferences.

Whether the high price equilibrium exists under the BDRA depends on the level of advantageous inequity aversion (β) in the population. We computed and display in Table 3 the minimum level of aversion to advantageous inequality $\underline{\beta}^j$ that is necessary to reach a quality level $j > 1$. The requirements are the same for high and low value treatments and for both formats.

Whether there is sufficient advantageous inequality aversion among our participants is an empirical question. There are some studies that were designed specifically to measure inequality aversion. For example,

Table 1. Parameter Values

Quality level q	1	2	3	4	5	6	7
Costs $c(q)$	10	20	30	40	50	60	70
Value low: $v_L(q)$	15	80	130	180	220	250	270
Value high: $v_H(q)$	115	180	230	280	320	350	370

Table 2. Propositions and Hypotheses

<table>
<tr><td colspan="2" align="center">Standard theory</td></tr>
<tr>
<td>**Proposition 1.** <i>In each subgame perfect equilibrium of the Auction and the BDRA, the price is equal to c^1 or equal to $c^1 + \Delta$, the minimum quality q^1 is provided, and trade takes place.</i></td>
<td>**Hypothesis 1.** <i>In both procurement mechanisms, (a) contract prices will not be larger than $c(q^1) + \Delta = 11$, (b) suppliers will provide the minimum quality q^1 regardless of their bid, and (c) if the buyer accepts an offer in the BDRA, it will be the lowest of the submitted offers.</i></td>
</tr>
<tr><td colspan="2" align="center">Social preferences</td></tr>
<tr>
<td>**Proposition 2.** <i>For prices larger than $\underline{b}^j$ with $j > 1$, suppliers strictly prefer providing quality level q^j over all lower quality levels.</i>

Proposition 3. <i>An upward shift of the valuations from $v(q)$ to $v(q) + \phi$ does not affect the implementability of quality levels but increases the prices that are necessary to implement a certain quality level q^j with $j > 1$.</i>

Proposition 4. (a) <i>In each Auction, there exists a subgame perfect low-price equilibrium in which all suppliers bid $\underline{b}^1$, the buyer accepts, and the selected supplier provides the lowest quality level q^1.</i> (b) <i>In each subgame perfect high-price equilibrium of an Auction, all suppliers place the same bid $\hat{b} \in \mathcal{B}_{\beta < 1/2} \setminus \underline{b}^1$, and the buyer accepts. The bid $\hat{b} \in \mathcal{B}_{\beta < 1/2} \setminus \underline{b}^1$ can only be an equilibrium bid if $w\left(q^*(\hat{b} - \Delta), \hat{b} - \Delta\right) < 0.$</i>

Proposition 5. <i>If $\beta < 1/2$, all suppliers place the same bid from the set $\mathcal{B}_{\beta < 1/2}$, and trade takes place in each subgame perfect equilibrium of the BDRA. Furthermore, the equilibrium bid must be larger than or equal to the buyer's globally preferred bid b^*. If $\beta > 1/2$, all suppliers bid $b^*_{\beta > 1/2}$, and trade takes place in the unique subgame perfect (high-price) equilibrium.</i></td>
<td>**Hypothesis 2.** <i>There will be a positive relationship between prices and qualities (i.e., higher prices will, on average, result in higher qualities).</i>

Hypothesis 3. <i>Average BDRA prices will be higher in the high than in the low condition.</i>

Hypothesis 4. <i>Prices and quality levels in the BDRA will be higher than in the Auction.</i></td>
</tr>
</table>

a study by Blanco et al. (2011) uses an experiment to measure individual inequity aversion parameters for the model by Fehr and Schmidt (1999). In their paper, they report point estimates for 61 participants and find that on aggregate these levels are similar to the parameter distribution assumed by Fehr and Schmidt (1999). In their study, the average estimate of the β parameter is 0.47, and approximately 80% of the subjects have $\beta > 0.167$. This implies that the majority of suppliers can be expected to deliver quality of at least q^4 if the price is sufficiently high. Hence, buyers can safely accept prices well above 100.[11]

Given this empirical evidence, Hypothesis 2 predicts a positive correlation between prices and qualities. This hypothesis also implies that bids above $c^1 + \Delta = 11$ in the BDRA should be accepted and should result in an expected quality above q^1.

In terms of the differences between the high and low value conditions, our model predicts that in the BDRA the manipulation will induce higher prices in the high than in the low condition. This is stated in Hypothesis 3.

Our model predicts that a high price equilibrium exists in the BDRA but may not exist in the Auction. Hypothesis 4 states qualitative differences between Auction and BDRA that our model implies—namely,

that the BDRA will result in higher prices and higher quality than the Auction.[12]

4. Experimental Results

Table 4 summarizes average quality levels, prices, costs, profits, and acceptance rates in the four treatments. We can reject most parts of Hypothesis 1 (the only exception is that the average buyer profit in the Auction/low treatment is not significantly different from 5). Aside from this, average quality levels are above 1, prices are above 11, buyer profits are above 5 in the low treatment and below 105 in the high treatment, and winner profits are above zero.[13] Also, prices above 15 are accepted quite often, as we can see from the last column of Table 4. The fact that BDRA quality

Table 3. Minimum Requirements for the Provision of High Quality

Level	2	3	4	5	6	7
$\underline{\beta}^j$	0.133	0.167	0.167	0.200	0.250	0.333

Notes. Displayed are minimum levels of aversion to advantageous inequality that are necessary for the implementation of the different quality levels. These values do not differ between the low valuation treatment and the high valuation treatment.

Table 4. Averages and Standard Deviations Based on Session Averages

	Quality	Price	Costs	Buyer's Profit	Selected Supplier's Profit	Acceptance Rate
Auction/low	1.91*	63.78	19.14*	3.33**	44.64	0.48**
	(0.27)	(9.61)	(2.73)	(4.66)	(7.02)	(0.09)
BDRA/low	3.43	109.82	34.35	21.31**	75.50*	0.74**
	(0.36)	(10.48)	(3.58)	(5.33)	(7.65)	(0.06)
p-value	0.0104	0.0104	0.0104	0.0782	0.0163	0.0374
Auction/high	1.31	68.05	13.10	60.23	54.95	0.92
	(0.11)	(10.47)	(1.10)	(6.02)	(9.51)	(0.02)
BDRA/high	3.20	138.80	32.02	80.27	106.78	0.95
	(0.46)	(17.26)	(4.58)	(11.32)	(13.58)	(0.01)
p-value	0.0547	0.0104	0.0547	0.2002	0.0163	0.2607

Note. Displayed are the averages of the key parameters for Auction and BDRA based on cohort averages.
    *Average in the low condition is significantly different from the high condition at the 0.1 level.
    **Significance at the 0.05 level [*p*-values are based on the nonparametric Wilcoxon-Mann-Whitney test comparing the two formats (Auction versus BDRA), taking each cohort as one independent observation].

levels are above 1 and prices are above 11 is consistent with Hypothesis 2.

Hypothesis 4 is also supported because accepted prices and provided quality levels are significantly higher in the BDRA than in the Auction in both high and low value conditions (see the third and sixth rows and in Table 4). In the experiment setting, higher quality implies higher efficiency if trade takes place. In addition to higher average quality, the BDRA also has a higher acceptance rate (in the low value condition), thereby further increasing the efficiency advantage.

Contrary to the standard theory, which predicts that the buyer extracts the entire surplus, the profit of the selected supplier is on average not lower than the buyer's profit in all four treatments. The buyer's profit is significantly lower than the selected supplier's profit in the low value condition ($p^{\text{Auction}} = 0.0277$ and $p^{\text{BDRA}} = 0.0277$) and is not significantly different in the high value condition ($p^{\text{Auction}} = 0.7532$ and $p^{\text{BDRA}} = 0.1159$). Suppliers were significantly better off in the BDRA than in the Auction. Similarly, buyers also earned on average higher profits in the BDRA than in the Auction (differences only weakly significant in the low value condition). However, accepting high bids in the BDRA also proved to be risky, as potential losses were substantial.

Figure 3 displays prices along with average quality levels for each price level. Consistent with Hypothesis 2, there is a significant positive correlation between the quality provided and the price (see also Table 5 for a more formal analysis). In the two Auction treatments, a large proportion of accepted prices were below 80 ECUs (55% in the low condition and 70% in the high condition), and in approximately 47% in the low condition and in 83% in the high condition of trades, the quality provided was 1. In another 20% of the low condition trades and 10% of the high condition trades, the quality was 2. The proportion of Auction trades that ended up being profitable for

the buyer was only 26% in the low condition, whereas in the high condition, this proportion was much larger (89%).

The BDRA results are quite different. Only 17% of the low condition and 19% of the high condition of accepted prices were below 80 ECUs. In only 25% of low condition and 35% of high condition of trades, the minimum level of quality was provided. The proportion of trades that were profitable for the buyer was 53% in the low condition and 81% in the high condition. Because of higher prices, however, losses were also higher in magnitude in the BDRA. Contrary to Hypothesis 1, the buyer selected the higher of the two offers in 45% of the low condition trades and 35% of the high condition trades in the BDRA. This was the case despite the fact that selecting the higher bid did not result either in a higher average level of quality ($p = 0.24$ in the low condition and $p = 0.11$ in the high condition) or in a higher buyer profit ($p = 0.89$ in the low condition and $p = 0.69$ in the high condition).

Figure 4(a) illustrates the average profit of a buyer as a function of the accepted price in the two Auctions treatments, and Figure 4(b) illustrates the average profit of a buyer as a function of the accepted price, in the two BDRA treatments. The more frequently a price was accepted, the larger the corresponding marker. The figure demonstrates that accepting a high bid in in the Auction usually does not pay, whereas high prices in the BDRA are often profitable, because it resulted in a higher average level of quality. Interestingly, in the BDRA, the average profit does not seem to be monotonically increasing or decreasing in the accepted price. There appears to be two price ranges (about 100 and between 150 and 200) that yield higher average buyer profits than prices outside of those ranges.

So far, our analysis focused only on successful trades. To gain a better understanding of the buyer's decision of which offer to accept, we conduct random-effects ordered logit regressions with the dependent variable

Figure 3. Observed Price-Quality Combinations in Auction and BDRA
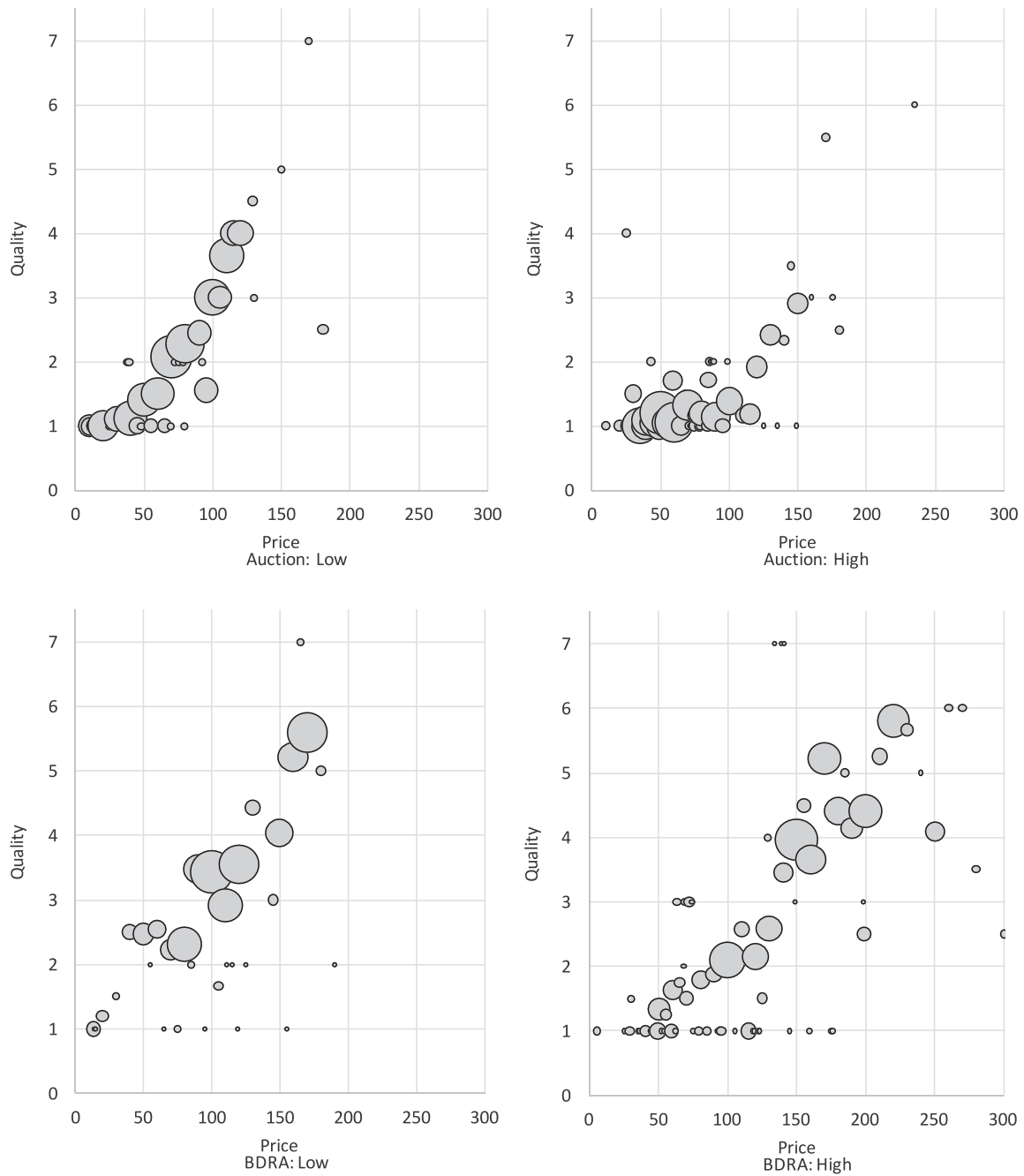
Notes. Displayed are all price-quality pairs in the Auction and the BDRA formats for low and high quality conditions. The size of a circle corresponds to the number of observations of a price-quality pair.

being the buyer's acceptance decision and independent variables listed in the first column of Table 6. The first two regressions estimate the buyer's acceptance decision taking the lowest offered price, the indicator variable for the high condition, and the current period into account. For both formats, the coefficient of *Period* is negative and significant, reflecting a decreasing acceptance rate, and the coefficient *High* is positive and significant,

reflecting the higher acceptance rates in the high value treatments.

The fourth and fifth columns of Table 6 present the results of regressions that also take into account the price the buyer paid and the quality received in the previous period. Under both formats, the level of quality delivered in the previous period influences the buyer's acceptance decision, whereas the price paid in the previous period

Figure 4. Average Buyer's Profit Depending on Accepted Price

(a)

Auction

(b)

BDRA
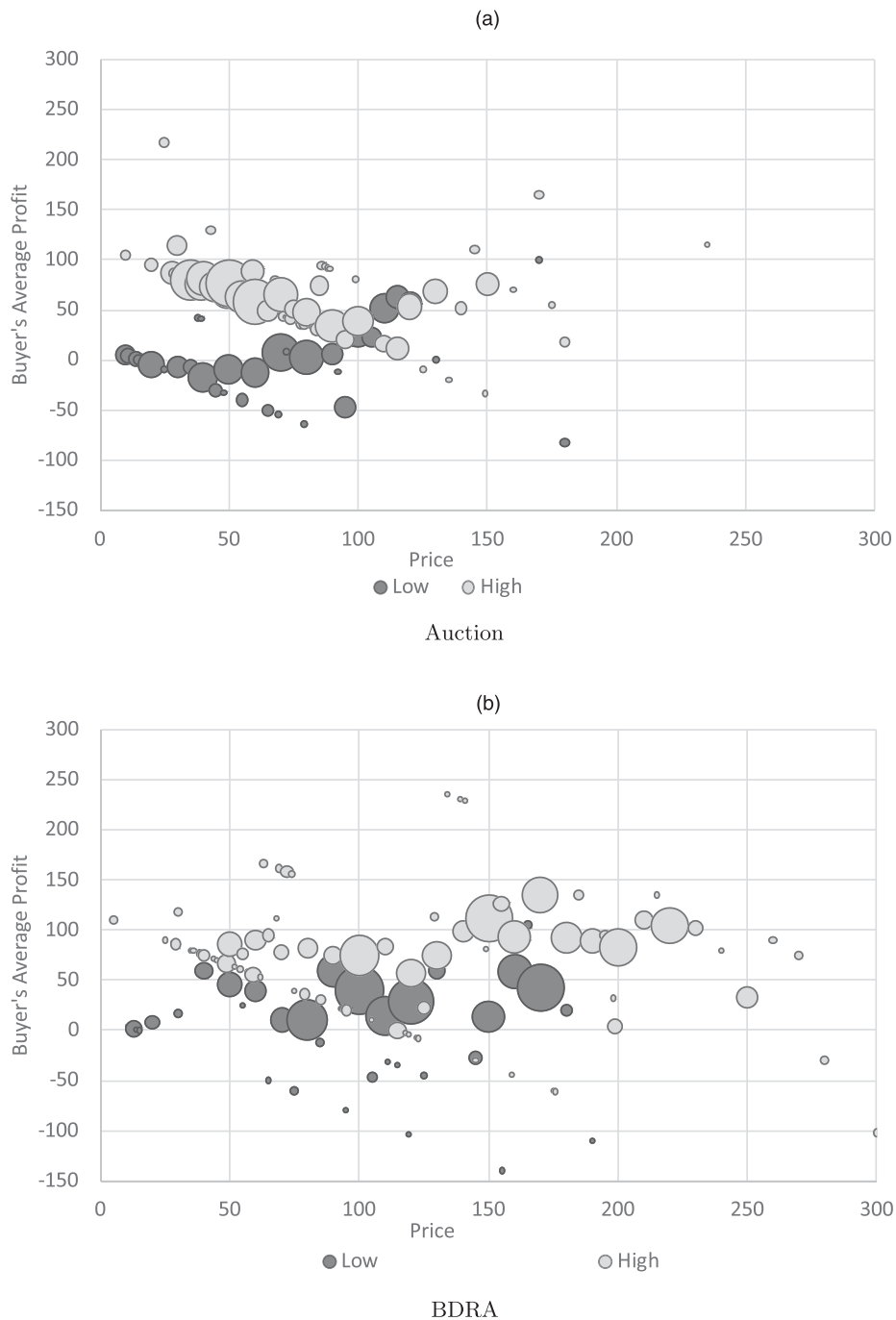
Note. The more frequently a price was accepted, the larger the corresponding marker.

has no effect on the likelihood of acceptance.[14] Also, the *Period* variable loses its significance. So the decreased acceptance rate that we observe can be due to either the decrease in quality provided over time or the increase in the submitted bids.

In Table 5 we present the results of a random-effects panel regression of suppliers' bidding behavior (second and third columns) and suppliers' quality provision decisions (fourth and fifth columns) over time. In both

formats, supplier's bid is positively influenced by the bid made by the supplier's former competitor in the previous period, but the way bidding behavior evolves over time is quite different for the two formats. In the Auction, bidders essentially learn to compete by bidding lower—they lower their bids when a trade took place last period, and there is also an additional downward time trend in bids, as is evidenced by the negative and significant coefficient of the *Period* variable. By contrast,

Table 5. Panel Regression of Suppliers' Bidding Behavior

	Bid		Quality	
	Auction	BDRA	Auction	BDRA
Competitor's Bid$_{t-1}$	0.183***	0.269***		
	(0.0226)	(0.0368)		
Price			0.01742***	0.02267***
			(0.0015)	(0.0013)
Trade$_{t-1}$	−5.892**	2.184	0.112*	0.2037**
	(1.889)	(2.084)	(0.0595)	(0.0936)
Period	−1.216***	0.695***	0.0012	−0.0014
	(0.142)	(0.252)	(0.0036)	(0.0060)
High	7.344	17.056**	−0.687***	−0.709***
	(5.297)	(7.289)	(0.0847)	(0.175)
Constant	83.92***	77.90***	0.719***	0.622***
	(4.694)	(5.951)	(0.1178)	(0.162)
Observations (groups)	3,232 (108)	3,132 (108)	2,020 (108)	2,020 (108)
R^2	0.1791	0.2099	0.3652	0.3204

Note. Standard errors are in parentheses.
**$p < 0.01$; ***$p < 0.001$.

bidders in the BDRA learn to increase their bids over time (positive and significant coefficient of the *Period* variable), and whether a trade took place last period does not have an effect. The bids are also significantly higher in the high value condition in the BDRA treatment, which supports Hypothesis 3, but not in the Auction treatment.

Quality provided under both formats is positively correlated with the current-period price and with whether the trade took place last period, so the primary difference in the performance under the two formats appears to be bidding behavior. In the Auction treatment, competition drives bids down, resulting in lower quality

and lower acceptance rates. In the BDRA treatment, competition does not drive prices down, because the buyer can award the contract to either bidder. Prices go up over time, as do quality levels.[15]

5. Conclusion

Auction theorists have shown that auctions represent the optimal way of selling items in a wide variety of settings (e.g., Bulow and Klemperer 1996). In procurement, however, things can be different, and there is both empirical and theoretical evidence that reverse auctions perform worse than other mechanisms if procurement

Table 6. Logit Panel Regression of Acceptance Probability

	Log acceptance probability			
	Auction	BDRA	Auction	BDRA
Lowest Bid	−0.0122***	−0.0107***	−0.0112**	−0.0080**
	(0.0029)	(0.0057)	(0.0043)	(0.00266)
Period	−0.0350***	−0.0314***	−0.0087	−0.0026
	(0.0066)	(0.0095)	(0.0124)	(0.013)
Quality$_{t-1}$			0.0105***	0.0092***
			(0.0022)	(0.0013)
Price$_{t-1}$			−0.0059	−5.64e–06
			(0.0046)	(0.0028)
High	3.04***	3.05***	3.16***	2.423***
	(0.437)	(0.615)	(0.4499)	(0.4507)
Constant	1.33 ***	2.48***	0.991***	1.10***
	(0.332)	(0.397)	(0.441)	(0.279)
Observations (groups)	1,620 (54)	1,620 (54)	1,015 (54)	1,172 (53)
Log likelihood	−775.61	−597.08	−397.22	−350.89

Notes. Standard errors are in parentheses. Regressions reported in the first two columns estimate the influence of the value of the lowest bid and the current period on buyer's acceptance probability. Regressions in the last two columns take also the quality the buyer received and the price he paid in the former period into account. The number of observations in these regressions is smaller because only those acceptance decisions are considered where the buyer traded in the period before.
*$p < 0.05$; ***$p < 0.01$.

projects are complex and complete contracts cannot be written. One of the explanations states that reverse auctions have a negative effect on the relationship between the buyer and the supplier, which is of special importance if opportunities for opportunistic behavior exist.

In this paper we investigate a setting in which the contract is incomplete and the supplier's actions after the contract has been awarded (decision about quality) has an effect on the buyer's welfare. In this setting, we compare the buyer–supplier relationships in binding price-based reverse auctions to those in buyer-determined reverse auctions Although standard theory predicts that both procurement mechanisms yield the same results, our data show substantial differences between the binding auction and the buyer-determined reverse auction. We observe that the buyer-determined reverse auction can be more profitable for both parties. It results in high prices, high quality, and more frequent trade. By contrast, prices, quality, and trade frequency are significantly lower in the binding auction. This implies a greater degree of efficiency in the buyer-determined reverse auction compared with the binding auction.

We find that our data can be organized using the theory based on other-regarding preferences in the form of inequity aversion. This theory assumes that individuals do not only seek to maximize their own profit but also care about how profits are distributed. The model can explain why a supplier, who receives a payment well above his cost in a buyer-determined reverse auction, voluntarily provides high quality but competes down to cost and provides only minimum quality in a binding reverse auction. More broadly, our work hints at the fact that the choice of trading institution can play an important a role in inducing prosocial behavior. By allowing buyers to choose sellers who do not necessarily have the lowest price, the BDRA can potentially encourage prosocial business relationships.

Even though our theoretical model and our hypothesis are based on an outcome-based model that considers only distributional fairness concerns, we do not want to claim that inequity aversion is the only possible or relevant explanation. There are also well-established intention-based reciprocity models (e.g., Rabin 1993 and Dufwenberg and Kirchsteiger 2004), and intention-based motives probably also play a role in real settings. We opted to use inequality aversion model because in our setting, deviations from the predictions of standard theory are due to prosocial behavior rather than antisocial behavior, and Fehr and Schmidt (2006) in their overview article argue that prosocial behavior can often be well explained by distributive fairness concerns, whereas intention-based reciprocity is rather important in explaining antisocial behavior, such as punishment or spite. Another indication that reciprocity may not be playing the main role is that the quality provided in the BDRA is not significantly

increased when the buyer awards the contract to the bidder who submitted the higher bid.[16]

The main managerial implication of our study, for procurement, is that too much competition may be counterproductive. When prices are too low, they are likely to indicate that the supplier will deliver low quality. Therefore, buyers should not necessarily strive to cut their suppliers' margins when contracts are incomplete. Similarly, suppliers, when competing in BDRA, can set higher prices to signal their intention to deliver higher quality. Of course, accepting higher prices may be risky for buyers, and therefore, the buyers should try to mitigate this risk by linking performance to future contracts or, alternatively, to reputation (Brosig-Koch and Heinrich 2012).

Acknowledgments

Appendix

Here, we apply the concept of a QRE to our model with social preferences and thereby analyze how predictions change if we allow for mistakes. The QRE concept was first introduced by McKelvey and Palfrey (1995) for normal-form games and then extended to extensive-form games by McKelvey and Palfrey (1998). The basic idea is that individuals do not always take the best action available but play better actions more often. This means that the probability with which a certain action is played is determined by the expected utility associated with this action. This is sometimes referred to as noisy decision making.

We consider a logit QRE, which implies that subjects have a logit choice function. Consider a subject with a discrete set of possible actions $S = \{s_1, \dots, s_m\}$, and let $V(s_j)$ with $s_j \in S$ denote the expected utility associated with the choice of action s_j. Then the probability that action s_j is chosen is given by

$$\Pr(s_j) = \frac{e^{V(s_j)/\lambda}}{\sum_k e^{V(s_k)/\lambda}}.$$

The parameter $\lambda > 0$ is often referred to as the noise or precision parameter, and it determines the shape of the probability distribution. The smaller the λ, the smaller the noise, and the more probability weight is on better compared with worse actions. This behavior can be interpreted as bounded rationality in the sense that individuals fail to take the optimal action and hence make mistakes. In this case, λ reflects how frequent and pronounced these errors are. Another interpretation is to consider λ as a measure of heterogeneity among subjects. Here, one would assume that the considered utility function is correct on average but that individuals differ with respect to their exact preferences. Then one would interpret the predicted behavior based on unobservable heterogeneity among subjects. The smaller the λ, the more homogeneous the population, and the better the fit of the average utility function to each individual—hence, the more frequently the action that maximizes the average utility is chosen.

Suppose, for example, that given a certain price we observe that a quality of q^1 is provided in 70% of the cases and a quality of q^2 is provided in the remaining 30% of the cases. Then it might be the case that suppliers prefer to provide

quality level q^1 but sometimes make mistakes and provide quality q^2. The other interpretation would assume that the specification of the suppliers' utility function is only correct on average, whereas individual utility functions might differ. In this case the 30% group might represent suppliers that are more prosocial than the rest. We will interpret λ as a mistake rate. The larger the λ, the more frequent and the more pronounced the mistakes. If $\lambda \to \infty$, behavior is independent of preferences and pure noise. In the limit case of $\lambda \to 0$, subjects make no mistakes and always play mutually best responses. In this case the limit QRE corresponds to a Nash equilibrium of the underlying game.

The main consequence of the QRE concept is that reaction functions become smooth; this implies that expected qualities and acceptance probabilities are continuous in bids. Consider the following comparison with the underlying social preference model described in the former section. Equation (4) implies that all selected suppliers will provide quality level q^j with $j > 1$ if the price is $\underline{b}^j$. However, if the price is equal to $\underline{b}^j - \Delta$, all suppliers only provide the lower quality level q^{j-1}, no matter how small Δ is. As a consequence, it may well be the case that the buyer accepts bid $\underline{b}^j$ but rejects the bid $\underline{b}^j - \Delta$. In contrast to that, the QRE concept implies that the behavior by the buyer associated with $\underline{b}^j$ and $\underline{b}^j - \Delta$ differs less if λ gets larger. Thus, the difference between the expected quality associated with $\underline{b}^j$ and $\underline{b}^j - \Delta$ becomes smaller, and in turn, the probability that bid $\underline{b}^j$ is accepted by the buyer gets closer to the probability that the bid $\underline{b}^j - \Delta$ would be accepted if λ gets large.

In the following we will apply the QRE concept to our social preference model. First, we will demonstrate that it implies a positive correlation between prices and expected quality. Second, we examine the existence of a QRE in which the equilibrium strategies of the underlying game represent best responses for small λ. Then we will show how mistakes affect the optimal bidding behavior in the Auction and the BDRA and prove that optimal bids in the Auction are smaller than optimal bids in the BDRA if λ is sufficiently large.

Proposition A.1. *For all $\lambda > 0$, the expected quality is strictly increasing in the price for all prices between $[v(q^1) + c(q^1)]/2$ and $[v(q^m) + c(q^m)]/2$ if either $\alpha > 0$ or $\beta > 0$.*

Proof. The probability that a supplier will provide quality level q^j given a price b is given by

$$\Pr(q^j, b) = \frac{e^{u(q^j, b)/\lambda}}{\sum_k e^{u(q^k, b)/\lambda}}.$$

The utilities $u(q^j, b)$ are defined in (2). For prices smaller than $[v(q^1) + c(q^1)]/2$, a price increase of one unit results in a utility increase of $1 + 2\alpha$ independent of the quality level q^j. Similarly, for prices larger than $[v(q^m) + c(q^m)]/2$, a price increase of one unit results in a utility change of $1 - 2\beta$ independent of the quality level q^j. Hence, for prices smaller than $[v(q^1) + c(q^1)]/2$ or larger than $[v(q^m) + c(q^m)]/2$, all price changes of the same size result in the same changes of expected quality.

For prices larger than $[v(q^j) + c(q^j)]/2$ and smaller than $[v(q^{j+1}) + c(q^{j+1})]/2$, a price change of one unit increases the utility from providing quality q^{j+1} or higher by $1 + 2\alpha$ but increases the utility from providing quality level q^j or lower

only by $1 - 2\beta$. Hence, the expected quality is strictly increasing in the price for all prices between $[v(q^1) + c(q^1)]/2$ and $[v(q^m) + c(q^m)]/2$. □

Proposition A.2. *In the Auction and the BDRA all equilibria of the underlying game in which suppliers expect a strictly positive utility represent a QRE if λ is sufficiently small.*

Proof. Given that the selected supplier's profit $u(q^1, \underline{b}^1)$ is strictly larger than zero, suppliers have a unique optimal bid as a response to each possible equilibrium bid. In other words, if all other suppliers place the equilibrium bid $\underline{b}^j$, then each supplier strictly prefers bidding $\underline{b}^j$ over all other bids. Hence, there is a λ sufficiently close to zero such that the equilibrium strategies represent best responses in a QRE.

If $u(q^1, \underline{b}^1)$ is equal to zero, there does not exist a QRE in which it is optimal for suppliers to bid $\underline{b}^1$, because for each $\lambda > 0$, all larger bids are associated with strictly more expected utility. In this case there also exists an equilibrium in the Auction in the underlying game in which all suppliers bid $\underline{b}^1 + \Delta$, and for λ sufficiently small, there exists a QRE in which bidding $\underline{b}^1 + \Delta$ is the best response. □

Next we will analyze the consequences on the optimal bidding behavior in the Auction and the BDRA. We start with the influence of mistakes of the buyer and, to isolate the effect, assume that suppliers make no mistakes. In the Auction a buyer can make two types of mistakes. She can either reject a bid she should accept or accept a bid she should reject. Both types of mistakes reduce the difference between the acceptance probabilities of different bids. Because only a sharp decrease of the acceptance probability can make it unattractive for suppliers to undercut their competitors, these mistakes put additional pressure on prices. If the buyer's mistake rate is sufficiently large in the Auction, only a low-price equilibrium can exist, because for all higher prices, suppliers would have an incentive to undercut their competitors. In the BDRA a buyer can also make other mistakes. She can reject a bid she should accept or accept a bid she should reject, but she can also choose a bid that is less attractive than other bids. As a consequence, and in contrast to the Auction, mistakes by the buyer reduce pressure on prices in the BDRA. The higher the mistake rate of the buyer, the smaller the influence of the own bid on being selected, and the more attractive it is for a supplier to place a high bid that results in a high utility in case of selection. This shows that a growing mistake rate by the buyer has opposing effects in the Auction and in the BDRA. It increases the incentive to undercut competitors in the Auction but to raise bids in the BDRA.

Mistakes by the supplier have similar effects on bidding behavior in the Auction and the BDRA. In the Auction a growing mistake rate implies that it becomes more likely to win for a bidder if he sets a higher price, as with some probability, the other bidder has made a mistake and set an even higher price himself. Hence, also the optimal bid grows. Similarly, a growing mistake rate in the BDRA implies that it becomes more likely that competitors place unattractive bids. Again, the optimal response is to increase the own bid. Mistakes of the selected supplier regarding the quality choice also affect the optimal bidding behavior in both mechanisms in the same way.

With λ sufficiently large, these effects are shown to determine the equilibrium behavior.

Proposition A.3. *If $\beta < 1/2$, the following holds true:*

(1) *The optimal bid in the Auction is equal to $\underline{b}^1$ and equal to $v(q^m)$ in the BDRA if suppliers make no mistakes and the buyer's mistake rate λ is sufficiently large.*

(2) *The optimal bid in the Auction is smaller than the optimal bid in the BDRA if the buyer's and suppliers' mistake rates λ are sufficiently large.*

Proof. Consider a setting in which only the buyer makes mistakes, and suppose there is an Auction in which all suppliers place an equilibrium bid $\underline{b}^j$ with $j > 1$. Let $\mathrm{Pr}_{win}^{\underline{b}^j}(b)$ denote the probability that a bidder bidding b wins the Auction when the $n - 1$ competitors bid $\underline{b}^j$. In the Auction we have

$$\mathrm{Pr}_{win}^{\underline{b}^j}(b) = \begin{cases} 1 & \text{if } b < \underline{b}^j, \\ 1/n & \text{if } b = \underline{b}^j, \\ 0 & \text{if } b > \underline{b}^j. \end{cases}$$

Furthermore, let $\mathrm{Pr}_{accept}(b)$ denote the probability that the buyer wants to accept if the contract is offered at a price b.

Now consider a supplier's deviation incentives. Obviously, deviation incentives to bids larger than $\underline{b}^j$ do not exist because all such bids are associated with a zero winning probability. A supplier has an incentive to bid $\underline{b}^j - \Delta$ instead of $\underline{b}^j$ if

$$u(q^{j-1}, \underline{b}^j - \Delta) \cdot \mathrm{Pr}_{accept}(\underline{b}^j - \Delta) > u(q^j, \underline{b}^j) \cdot \mathrm{Pr}_{accept}(\underline{b}^j)/n.$$

Because the buyer prefers $\underline{b}^j$ over $\underline{b}^j - \Delta$, we know that the acceptance probability $\mathrm{Pr}_{accept}(\underline{b}^j)$ is larger than $\mathrm{Pr}_{accept}(\underline{b}^j - \Delta)$. However, the difference between the two probabilities is continuously decreasing in the buyer's mistake rate λ and becomes zero if $\lambda \to \infty$. Hence, there exists a critical value of λ such that for all larger values the increased winning probability from bidding $\underline{b}^j - \Delta$ overcompensates the lower acceptance probability.

With a similar argument, also $\underline{b}^j - \Delta$ cannot be an equilibrium if λ is sufficiently large, as a supplier has an incentive to undercut the others. Independent of the buyer's λ, there always exists a mutual best response such that all suppliers bid $\underline{b}^1$. Thus, for $\lambda \to \infty$, this is the only possible equilibrium bid in the Auction.

In a BDRA the probability that the buyer wants to accept if the contract is offered at a price b is the same as in the Auction. In contrast to the Auction, the buyer does not always choose the lowest bid in the BDRA before she decides about its acceptance. However, the buyer is more likely to select a more attractive bid than a less attractive bid. Let $\mathrm{Pr}_{choose}^{\underline{b}^j}(b)$ denote the probability that the buyer chooses bid b if all other suppliers bid $\underline{b}^j$. Because the buyer prefers $\underline{b}^j$ over the neighboring bids $\underline{b}^j - \Delta$ and $\underline{b}^j + \Delta$, we also know that $\mathrm{Pr}_{choose}^{\underline{b}^j}(\underline{b}^j) > \mathrm{Pr}_{choose}^{\underline{b}^j}(\underline{b}^j + \Delta)$ and $\mathrm{Pr}_{choose}^{\underline{b}^j}(\underline{b}^j) > \mathrm{Pr}_{choose}^{\underline{b}^j}(\underline{b}^j - \Delta)$.

Now consider a supplier's deviation incentives. Obviously, deviation incentives to bid $\underline{b}^j - \Delta$ do not exist because this bid is associated with a lower probability of being selected and a lower utility in case of selection compared with $\underline{b}^j$. Hence, bidding $\underline{b}^j - \Delta$ is dominated by $\underline{b}^j$. However, it might be optimal for a supplier to deviate to $\underline{b}^j + \Delta$ because this bid is associated with a higher utility than $\underline{b}^j$ in case of selection. A supplier wants to deviate to $\underline{b}^j + \Delta$ in a BDRA if

$$u(q^j, \underline{b}^j + \Delta) \cdot \mathrm{Pr}_{accept}(\underline{b}^j + \Delta) \cdot \mathrm{Pr}_{choose}^{\underline{b}^j}(\underline{b}^j + \Delta)$$
$$> u(q^j, \underline{b}^j) \cdot \mathrm{Pr}_{accept}(\underline{b}^j) \cdot \mathrm{Pr}_{choose}^{\underline{b}^j}(\underline{b}^j). \tag{A.1}$$

Here, $\mathrm{Pr}_{choose}^{\underline{b}^j}(b)$ denotes the probability that the buyer chooses bid b if all other suppliers bid $\underline{b}^j$. The difference between the selection probabilities given as the product of being chosen and accepted is continuously decreasing in λ and approaches zero if $\lambda \to \infty$. For $\lambda \to \infty$, a supplier always wants to increase his bid. Hence, the optimal bid for a supplier in the BDRA is $v(q^m)$ as his utility function is increasing in the price for $\beta < 1/2$.[17] This shows part (1) of the proposition. In the BDRA the optimal bidding behavior does not change if suppliers make mistakes. It is still optimal for every supplier to make the largest bid $v(q^m)$ if the buyer is sufficiently likely to select this bid. Because mistakes by suppliers decrease pressure on prices, a growing mistake rate leads to higher bids in the Auction. However, even if the suppliers' mistake rate becomes arbitrarily large, it is still optimal for suppliers to bid below $v(q^m)$. Bidding $v(q^m)$ would imply that the suppliers loses as soon as a competitor offers a different (lower) bid. Thus the optimal response will be to make a lower bid with some higher selection probability.[18] Hence, we conclude that for $\lambda \to \infty$, the optimal bid for suppliers in the BDRA is larger than in the Auction. □

The QRE analysis showed that all the equilibria derived in the social preference section with homogeneous individuals are limit QRE and can still exist if subjects make small mistakes or are slightly heterogeneous. Furthermore, we could show that the effect of mistakes by the buyer has opposing effects on optimal bidding behavior in the Auction and the BDRA. Finally, we demonstrated that optimal bids in the Auction are smaller than in the BDRA if λ is sufficiently large.

Endnotes

[1] Mayer et al. (1995, p. 712) define trust as "the willingness of a party to be vulnerable to the actions of another party based on the expectation that the other will perform a particular action important to the trustor, irrespective of the ability to monitor or control that other party," and Özer and Zheng (2018, p. 494) provide a similar definition that to "trust is to behave voluntarily in a way to accept vulnerability due to uncertain behavior of another (the trustee), based upon the expectation of a positive outcome."

[2] Which mechanism performs better from the buyer's viewpoint depends on the specific environment. If nonprice attributes are important and the buyer has little uncertainty about suppliers' costs, then a buyer-determined auction performs better than a binding price-based auction from the buyer's point of view. Alternatively, if nonprice attributes are of little importance for the buyer and expected cost reductions as a result of competition large, then a price-based auction performs better.

[3] It cannot be ruled out that some individuals derive additional utility from being better off than others ($\beta < 0$). However, we do not explicitly model this case, because such suppliers act like completely selfish individuals ($\beta = 0$) and always provide lowest quality.

[4] Assuming that the buyer and all suppliers compare their profits to each other does not change the main results. We will mention the

changes implied by the alternative specification of the reference group when relevant.

[5] If the buyer and all suppliers compared their profits to each other, the lowest acceptable price for a supplier $\underline{b}^1$ would be equal to $c(q^1)$; if otherwise, a competitor was selected.

[6] The alternative specification of the reference group would imply a different threshold value.

[7] If $\beta = 1/2$, the buyer is indifferent between all prices that implement the same quality level, as long as the selected supplier's profit does not exceed the buyer's profit.

[8] We assume that because of discreteness of the bid grid $\mathcal{G}$ the selected supplier's utility was $u(q^1, \underline{b}^1) > 0$. If this was not the case, and $u(q^1, \underline{b}^1) = 0$, there would also exist another equilibrium in which all suppliers bid $\underline{b}^1 + \Delta$.

[9] The alternative specification of the reference group implies stronger deviation incentives, because suppliers derive negative utility if a competitor is selected which increases deviation incentives.

[10] We selected the parameters in a way that existing estimates of inequity aversion predict differences between our treatments. Our motivation to consider a concave function is to reflect that the selected supplier has different options to increase the value of the good for the buyer and will first choose those that are least expensive.

[11] Yang et al. (2016) also estimate inequality aversion parameters but do not provide individual estimates.

[12] In line with Hypothesis 4, Proposition A.3, based on a QRE analysis that is relegated to the appendix, implies that if λ is sufficiently large, bids, and hence also qualities, in the Auction are smaller than bids in the BDRA.

[13] We use cohort as a unit of analysis, Wilcoxon signed rank test for one sample comparisons, and Wilcoxon-Mann-Whitney test for two-sample comparisons.

[14] In view of the fact that buyers trading in the BDRA selected the higher bid in 46% of cases, the same regressions as in Table 6 were run with the higher, instead of the lower, bid as an explanatory variable for the BDRA treatment. None of the coefficients were found to differ significantly.

[15] We also conducted the BDRA quality regression with an indicator variable for when the chosen bid was the high bid. This variable was not significant with $p = 0.307$.

[16] In fact, intention-based reciprocity models cannot be applied in a straightforward manner to our simple procurement interaction setting. Dufwenberg and Kirchsteiger (2004) provide the framework to consider intention-based reciprocity in dynamic games. The application of this concept is restricted to games in which each agent moves exactly once and all preceding choices are observable. Because the selected supplier moves twice, our setting is not covered. If we alternatively assume that suppliers make the decision about price and quality at the same time, the observability requirement would be violated. This is necessary to classify actions of other players as kind or unkind.

[17] If $\beta > 1/2$, the optimal bid for suppliers in the BDRA would be $b^*_{\beta > 1/2} < v(q^m)$.

[18] If $\beta > 1/2$, the optimal bid for suppliers in the BDRA would be $b^*_{\beta > 1/2}$, and one could construct a bid grid such that this was also the optimal bid in the Auction.

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