

# PROCUREMENT UNDER PUBLIC SCRUTINY: AUCTIONS VS. NEGOTIATIONS

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*ABSTRACT.* We compare two commonly used mechanisms in public procurement: auctions and negotiations. The execution of the procurement mechanism is delegated to an agent of the buyer. The agent has private information about the buyer's preferences and may collude with one of the sellers. We provide a general characterization of both mechanisms based on public scrutiny requirements and show – contrary to conventional wisdom – that an intransparent negotiation always yields higher social surplus than a transparent auction. Moreover, there exists a lower bound on the number of sellers such that the negotiation also generates a higher buyer surplus. If the buyer can employ the optimal favoritism-proof mechanism, the winning probability of the favorite seller is independent of the private information of the agent. The optimal mechanism combines features of both the auction and the negotiation.

*JEL classification:* D44, D73, L13, H57

*Keywords:* Corruption, Auctions, Negotiations, Public procurement

## 1. INTRODUCTION

Auctions are believed to be transparent mechanisms and thus less prone to favoritism than private negotiations. For instance, Paul Klemperer (2000) argues that “..., allocation by bureaucrats leads to the perception – if not the reality – of favoritism and corruption. In fact some governments have probably chosen beauty contests [over auctions] precisely because they create conditions for favoring “national champions” over foreign competitors. This is unlikely to benefit consumers and taxpayers.”<sup>1</sup>

The perception that auctions are transparent mechanisms stems from the fact that auctions are executed publicly, whereas negotiations are conducted privately. Hence, in an auction all relevant parameters and rules have to be defined *before* the bidders submit their offers and it is apparent

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We would like to thank Johannes Hörner, Philippe Jehiel, Elena Katok, Alexander Rasch, and the participants of the seminars at Paris School of Economics, Penn State and Yale University and of the workshop of the DFG research group “Design and Behavior” for helpful comments and discussions. Financial support from the German Science Foundation (DFG) through the research group “Design and Behavior” and the Fulbright Commission is gratefully acknowledged. Substantial parts of this paper were written when the first author stayed at Yale University in 2011/2012. The author thanks the department of economics for its hospitality.

<sup>1</sup>More recently Subramanian (2010) states that “[a]uctions are more transparent processes than private negotiations, so if transparency is important, an auction is better. This is the reason that most public procurement contracts [...] are done through auctions, particularly when the government is looking to defuse criticisms of corruption or favoritism.” Moreover, Wolf (2000) argues that “it [the auction] is the fairest [mechanism] because it ensures that the economic value goes to the community, while eliminating the favoritism and corruption inherent in bureaucratic discretion.”

whether the implemented procedures have been followed. Contrary to that, in a negotiation it is impossible to reconstruct the decision process and only the final decision becomes public.

However, public scrutiny does not imply that auctions are favoritism proof, as the parameters and procedures of an auction may be chosen in a way that benefits one of the sellers *before* the auction has even started. Moreover, even though a negotiation is conducted behind closed doors, the final outcome of the process has to be justified to the public *after* all offers have been collected. Thus, some public scrutiny cannot be avoided in a negotiation.<sup>2</sup>

This paper focuses on the definition and comparison of auctions and negotiations in the presence of favoritism. For both processes we consider a procurement setting with sellers that are horizontally differentiated with respect to the specification of the procured project.<sup>3</sup> Buyer surplus depends not only on the final price but also on the implemented specification. The buyer has to delegate the execution of the procurement process to an agent who privately observes the specification preference of the buyer and colludes with one – exogenously chosen – seller.<sup>4</sup> The agent maximizes the surplus of his preferred seller and has a weak preference for honesty, i.e., he prefers not to manipulate the process if his preferred seller cannot strictly benefit from manipulation.

We argue that the main difference between auctions and negotiations in terms of transparency is that in an auction public scrutiny is imposed *before* the agent collects the offers of the sellers, whereas in the negotiation public scrutiny is imposed *after* collecting the offers. Hence, public scrutiny in an auction restricts the choice of the process (*process scrutiny*), whereas in the negotiation public scrutiny merely places restrictions on the final decision of the agent (*outcome scrutiny*). In our set-up, the manipulation power of the agent stems from the fact that the preferred specification of the buyer is private knowledge to the agent. Thus, process scrutiny in the auction implies that the agent has to report the preferred specification of the buyer before the process and the implemented procedure has to be optimal given his report and the goals of the buyer.<sup>5</sup> In the negotiation, outcome scrutiny implies that the agent can report the preferred specification of the buyer after the process

<sup>2</sup>This argument carries over to private auctions and negotiations. Even though, private procurement is not conducted publicly, the managers still have to report to the shareholders of the procuring company.

<sup>3</sup>For example, in engineering plastics (Polyamide, Polycarbonate) there is a trade-off between rigidity and flexibility. Different grades of plastics from different suppliers have different characteristics. Prior to the procurement auction, the project team decides on the optimal project specification (i.e., relation of rigidity and flexibility).

<sup>4</sup>The assumption that the agent colludes with one specific seller resembles many real-life situations in public procurement. For example, Laffont and Tirole (1991) point out that “[t]here has been much concern that the auction designer may prefer or collude with a specific buyer. And indeed most military or governmental markets acquisition regulations go to a great length to impose rules aimed at curbing favoritism. Similarly, the European Economic Commission, alarmed by the abnormally large percentage (above 95% in most countries) of government contracts awarded to domestic firms is trying to design rules that would foster fairer competition between domestic and foreign suppliers and would fit better than recent experience with the aim of fully opening borders ...”

<sup>5</sup>If the buyer is concerned with social surplus, the agent has to implement the social-surplus optimal auction. If the buyer is concerned with his own surplus, the agent has to implement the buyer-surplus optimal auction. In both cases the agent can claim that this specification is the true specification of the buyer and that the procedure is optimal.

and the winning offer has to be optimal given his report.<sup>6</sup> How this offer was achieved is not salient to the public. Thus, in our analysis we do not restrict the agent to the use of a specific negotiation protocol but derive the outcome of the negotiation solely from the public scrutiny constraints and the commitment technology of the agent.

One of our main insights is that the decision whether to manipulate the auction is different from the decision whether to manipulate the negotiation. In the auction, the decision to manipulate has to be taken before the sellers submit their offers, whereas in the negotiation, the decision to manipulate can be taken after the sellers have submitted their offers. Hence, the agent always manipulates the auction, whereas in the negotiation, the decision to manipulate depends on the realized costs and specifications of the sellers. To get some intuition for this result, recall that in the negotiation the agent can observe the offers of the sellers before public scrutiny forces him to reveal the specification on which his allocation decision is based. Thus, the preferred specification of the buyer is only distorted if the favorite seller can benefit from the distortion ex-post. It follows that if the favorite seller turns out to be relatively weak, the specification is set optimally and the project is allocated efficiently among the honest sellers. In the auction, the details of the process have to be set prior to collecting the offers. Therefore, the auction is manipulated whenever the favorite seller can profit from manipulation ex-ante. Thus, manipulation takes place even if the favorite seller is relatively weak. It follows that even if the favorite seller fails to win the auction, the allocation among the honest sellers is distorted.

From the argument above it follows directly that the negotiation yields a higher social surplus than the auction. Beyond social surplus, we show that with two sellers the auction always generates a higher buyer surplus. This is due to the fact that the auction discriminates against the specification advantage gained through manipulation. Thus, the auction is less distorted towards the favorite seller and with two bidders this results in a higher buyer surplus. If the number of sellers is above two, either of the processes may generate the higher buyer surplus depending on the specifications of the sellers. We provide a sufficient condition such that the negotiation always leads to higher buyer surplus if the number of sellers is sufficiently large. This condition essentially ensures that the specifications of the sellers are dispersed such that manipulation of the negotiation takes place with low probability and that the allocation among the honest sellers is distorted in the auction. Both these effects work in favor of the negotiation if the number of sellers increases. First, manipulation in the negotiation becomes less likely and the negotiation allocates efficiently. Second, the difference in buyer surplus between the efficient and the buyer-surplus optimal allocation decreases. Thus, if the

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<sup>6</sup>In this case the agent can claim that this is the true specification of the buyer.

number of sellers becomes large, the negotiation converges to the social-surplus and buyer-surplus optimal outcome. This is not true for the auction which remains inefficient even if the number of sellers is large and thus also buyer-surplus suboptimal.

We proceed by discussing extensions of our model. We derive the optimal favoritism-proof mechanism and show that in every mechanism that is incentive compatible for the agent, the winning probability of the favorite seller cannot depend on the report of the agent. The resulting optimal favoritism-proof mechanism has features of both the auction and the negotiation: similar to the auction, the optimal mechanism limits the magnitude of manipulation by discriminating against the specification advantage arising from manipulation. Similar to the negotiation, whenever the favorite seller fails to win the project, the mechanism is not manipulated and the allocation among the honest sellers is not distorted.

In a symmetric setting, if the favorite seller is not exogenously given but chosen through a bribery contest, the differences between auctions and negotiations vanish. This is due to the fact that the offered bribes are independent from the true specification of the buyer. Hence, in a symmetric setting, the seller with the lowest cost of delivering the project will win the bribery contest, receive a specification advantage in both the auction and the negotiation, and thus win the project with probability one.

**Relation to the literature.** This paper brings together two strands of literature: the literature on favoritism in auctions, and the literature on the comparison of auctions and negotiations.

In most cases favoritism enters auctions through two different channels. First, the auctioneer can favor a seller by allowing him to adjust his bid in a first-price auction after observing all of the competing bids (right of first refusal or bid rigging). In this case the final allocation will be inefficient and the surplus of the buyer diminishes (Burguet and Perry, 2007; Cai et al. (2013); Compte et al., 2005; Menezes and Monteiro, 2006; Lengwiler and Wolfstetter, 2010). In our model, the auction takes place under public scrutiny. Thus, such a form of bid rigging cannot occur in the auction. In the negotiation bid rigging is possible as only the final outcome is subject to public scrutiny. Second, the auctioneer can manipulate the quality assessment of his favorite seller. This case is analyzed in Laffont and Tirole (1991), Burguet and Che (2004), Koessler and Lambert-Mogiliansky (2013), and Celentani and Ganuza (2002). We take a slightly different approach in assuming that the agent may misrepresent the preferences of the buyer rather than the quality assessment of the seller. This implies that favoritism not only distorts the allocation towards the favorite seller but may also distort the allocation among the honest sellers.

The second strand of literature is concerned with the comparison of auctions and negotiations. Bulow and Klemperer (1996) show that a simple auction with one additional bidder leads to higher revenues than the best mechanism without this bidder. The result by Bulow and Klemperer (1996) is often used to argue in favor of auctions. Bulow and Klemperer (2009) compare a standard English auction to a negotiation that is defined as a sequential procedure. They show that the auction fares better in terms of revenue although the negotiation is more efficient. This is due to the fact that entrants have to incur costs to learn their true valuation. Thus, bidders may prevent further entry with pre-emptive bids thereby capturing most of the efficiency gains. However, Davis et al. (2013) find in an experiment that in the same setting the negotiation outperforms the auction as subjects enter the negotiation more often than the auction and fail to employ the optimal pre-emptive bids.<sup>7</sup> The major challenge in comparing auctions and negotiations is to find a precise definition for each of the mechanisms. The sparse literature on this subject uses different approaches to tackle this issue. We argue that one of the main differences between both formats is the timing at which the precise rules are set and show that, contrary to previous works, negotiations can outperform auctions.

## 2. DEFINING “AUCTION” AND “NEGOTIATION”

**2.1. The Model.** A buyer procures one indivisible project from  $N$  risk neutral sellers. Let  $i \in \{1, \dots, N\}$  index the sellers. Each of the sellers has privately known costs  $c_i$  of delivering the project. It is common knowledge that  $c_i$  is distributed with c.d.f.  $F$  on support  $[0, \bar{c}]$ . The sellers are horizontally differentiated with respect to the specification of the project. This is captured for seller  $i$  by a given location  $q_i$  on a circle. The locations  $q_i$  on the circle are identified with numbers in  $[0, \bar{q}]$ , the northernmost point being both  $\bar{q}$  and 0 and the values increase in clockwise direction. For each  $i$ ,  $q_i$  is common knowledge among the buyer and the bidders. If seller  $i$  is selected to deliver the project at a price  $p$ , the value to the buyer is  $V - \|\theta - q_i\| - p$  with  $V \in \mathbb{R}_+$ .<sup>8</sup> The parameter  $\theta \in [0, \bar{q}]$  represents the desired specification of the buyer and is not observed by the buyer prior to the procurement process. The buyer believes that  $\theta$  is distributed with c.d.f.  $F_\theta$  on  $[0, \bar{q}]$  and  $\|\theta - q_i\|$  denotes the distance of locations along the shortest path on the perimeter of the circle.

The buyer has to delegate the execution of the procurement process to an agent who can privately observe the parameter  $\theta$  prior to procuring the project.<sup>9</sup> The agent colludes with one of the sellers.

<sup>7</sup>Other approaches to the theoretical comparison of auctions and negotiations include Bajari and Tadelis (2001), Fluck et al. (2007), McAdams and Schwarz (2006), or Manelli and Vincent (1995). Empirical studies have been conducted by Bajari et al. (2008), Bonaccorsi et al. (2000), Boone and Mulherin (2007), Chow et al. (2014), Kjerstad (2005), Lusht (1996), and Leffler et al. (2008).

<sup>8</sup>Assuming that the value to the buyer is  $V(\|\theta - q_i\|) - p$  for some concave function  $V$  does not change our results qualitatively.

<sup>9</sup>For example, we can think of the buyer being the public and the agent being a bureaucrat in charge of running a public procurement. In this case, it is easy to make sense of the assumption that the agent is better informed about

In what follows, let seller 1 be the seller in question.<sup>10</sup> The agent maximizes the surplus of seller 1 and has a weak preference for honesty, i.e., the agent only manipulates the mechanism if his favorite seller can strictly benefit from manipulation.<sup>11</sup>

To simplify the exposition, we make a standard assumption that ensures that it is always optimal to procure the object:

**Assumption 1.** *The following holds true for all  $c \in [0, \bar{c}]$ :*

$$(i) \quad V - \|q - \theta\| - c - F(c)/f(c) \geq 0 \text{ for all } q, \theta \in [0, \bar{q}]$$

$$(ii) \quad \psi(c) := c + F(c)/f(c) \text{ is strictly increasing in } c.$$

Assumption 1 is satisfied if  $F(c)/f(c)$  is non-decreasing and  $V$  is sufficiently large.

We define and compare two different procurement mechanisms – auctions and negotiations. The two mechanisms are derived from two different forms of public scrutiny: *process scrutiny* for the auction and *outcome scrutiny* for the negotiation. As a consequence, we impose that either the chosen process (*process scrutiny*) or the chosen outcome (*outcome scrutiny*) have to be optimal in the sense defined below.

**2.2. Auction.** An auction is conducted under *process scrutiny*, i.e., all relevant dimensions of the auction have to be made publicly available prior to its start. Hence, in an auction the agent has to set all relevant parameters and procedures before the sellers submit their offers.<sup>12</sup> As the choice of process by the agent is scrutinized, it has to be optimal given the information available to the public. Thus, the agent has to implement the optimal auction given some  $\hat{\theta} \in [0, \bar{q}]$ . What auction is considered optimal depends on the goals of the buyer: if the buyer is concerned with social surplus,

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the preferences of the buyer than the buyer himself. See Arozamena and Weinschelbaum (2009), Burguet and Perry (2007), Celentani and Ganuza (2002), or Laffont and Tirole (1991) for a description of such situations.

<sup>10</sup>We assume that the favorite seller is exogenously given. This assumption is a good approximation for many situations in public procurement where the agent may have a well established relationship with the domestic firm. The case that prior to the procurement the sellers can bribe the agent to become the favorite seller is analyzed in Section 5.

<sup>11</sup>We choose a set-up similar to Salop (1979) for two reasons. First, it ensures that there are always gains from manipulation. Second, it facilitates the analysis of bribery in Section 5 as through a simple assumption it allows for ex-ante symmetric bidders.

<sup>12</sup>For example, the public procurement directive of the European Union states: “The electronic auction shall be based [...] on prices and/or values of the features of the tenders, when the contract is awarded to the most economically advantageous tender. The specifications shall contain [...] the quantifiable features (figures and percentages) whose values are the subject of the electronic auction and the minimum differences when bidding. [...] The invitation shall state the mathematical formula to be used to determine automatic rankings, incorporating the weighting of all the award criteria.” (See the “*Directive 2004/18/EC of the European Parliament and of the Council of 31 March 2004 on the coordination of procedures for the award of public works contracts, public supply contracts and public service contracts*”).

the agent has to implement the social-surplus optimal auction. If the buyer is concerned with his own surplus, the agent has to implement the buyer-surplus optimal auction.<sup>13</sup>

The timing of the auction is the following:

- (i) The agent privately observes  $\theta$ .
- (ii) The agent publicly sets  $\hat{\theta} \in [0, \bar{q}]$  and commits to the optimal auction given the goals of the buyer.
- (iii) The sellers submit bids to the agent and the winning seller is determined.

**2.3. Negotiation.** The negotiation is conducted behind closed doors by the agent and the process cannot be publicly observed. Thus, in a negotiation the agent is not bound by the requirement to set all the relevant parameters and procedures in advance. He is rather free to choose his decision criteria at any time during the process. Even though the negotiation is conducted privately, the agent has to publicly justify his final decision. This *outcome scrutiny* places two restrictions on the decision of the agent.

First, the agent cannot prevent any of the bidders from submitting offers. This is due to the fact that in public procurement the contracting authority has “obligations regarding information [...]”. This takes the form of publishing information notices [...]” prior to the start of the procurement process.<sup>14</sup> Hence, all relevant sellers are aware that the project is being procured and could appeal against the exclusion of their offers.

Second, the agent has the obligation to reveal the winner of the process and the final agreement to the buyer. This is due to the fact that the sellers that did not win the project may request a statement by which means their offer is inferior to the offer of the winner.<sup>15</sup> In our set-up the specification of a seller and the price that she receives are the only relevant decision dimensions. Hence, this kind of public scrutiny places a restriction on the decision of the agent in the sense that the final winning offer has to maximize the value to the buyer for some  $\hat{\theta} \in [0, \bar{q}]$ .<sup>16</sup>

<sup>13</sup>In a related project, we investigate in how far public scrutiny restrictions allow the agent to rig the rules of the auction. For the purpose of the present paper, assuming that public scrutiny forces the agent to use an optimal auction is sufficient. Note that allowing the agent to implement an auction of his choice will reinforce our results in favor of the negotiation.

<sup>14</sup>See the above-mentioned “*Directive 2004/18/EC*” on public procurement.

<sup>15</sup>For example, the public procurement directive of the European Union states: “Each contracting authority shall provide information, as soon as possible, on the decisions reached concerning the award of a contract, including grounds for not awarding it. [...] On the request of the economic operator concerned [the contacting authority should provide information on] any unsuccessful candidate of the reasons for rejecting them; any tenderer who has made an admissible tender of the relative advantages of the tender selected, as well as the name of the economic operator chosen.” (See the above mentioned “*Directive 2004/18/EC*” on public procurement).

<sup>16</sup>In a sense, these two restrictions are minimal. If the agent is not obligated to consider at least one offer from each seller or if the outcome does not have to be the lowest offer, the agent can just give the project to his favorite seller at price  $V$  and discard all the other offers.

These two requirements place only little restriction on how the agent conducts the negotiation, in particular on how the agent may come to a final decision respecting the public scrutiny requirements. We explore the two fundamental ways for the agent to conduct the negotiation: he can commit to rejecting offers or he can commit to accepting offers. Rejecting offers implies that the agent can credibly tell a seller that his current offer does not suffice to win the project. A seller whose offer has been rejected may then resubmit a better offer. If the seller does not resubmit an offer, the agent can exclude him from the further process. If all offers but one have been rejected, this offer is the winning offer. This case is analyzed below. In contrast, accepting offers implies that the agent can credibly declare one offer as the winning offer and award the project to the respective seller without taking any further offers. This case is analyzed in Section 5.3.

If the agent can credibly reject offers, the negotiation takes the following form:

**Round 0:**

- (i) The agent privately observes  $\theta$ .

**Round 1:**

- (i) Each honest seller  $i \in \{2, \dots, N\}$  may submit an offer  $p_i^1$  to the agent.
- (ii) The agent observes the offers and shows them to seller 1. Seller 1 may submit an offer  $p_1^1$  or leave the negotiation.

**Round  $t$ :**

- (i) The agent rejects one or more offers of the sellers.
- (ii) A seller whose offer was rejected may submit an improved offer, i.e.,  $p_i^t < p_i^{t-1}$ . If she does not submit an improved offer, she is excluded from the further process.
- (iii) The agent observes the offers and shows them to seller 1. Seller 1 may submit an offer  $p_1^t$  or leave the negotiation.

**Final Round  $\tau$ :**

- (i) The negotiation ends if all but one seller were excluded from or left the negotiation. This seller is declared the winning seller.
- (ii) The agent sets the final specification  $\hat{\theta} \in [0, \bar{q}]$ . The winning seller is paid his final offer.

Public scrutiny implies that if seller  $i$  is the winning seller in Round  $\tau$ ,  $V - \|\hat{\theta} - q_i\| - p_i^\tau \geq \max_{j \neq i} (V - \|\hat{\theta} - q_j\| - \min_{t \leq \tau} p_j^t)$  has to hold.<sup>17</sup> To illustrate the public scrutiny requirement suppose that there are three offers  $p_i, p_j, p_k$  of bidders  $i, j, k$  with locations  $q_i, q_j, q_k$  on the table (see

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<sup>17</sup>To fully characterize the game, we assume that if the agent rejects all offers, or he violates public scrutiny, the agent pays a sufficiently large fine.



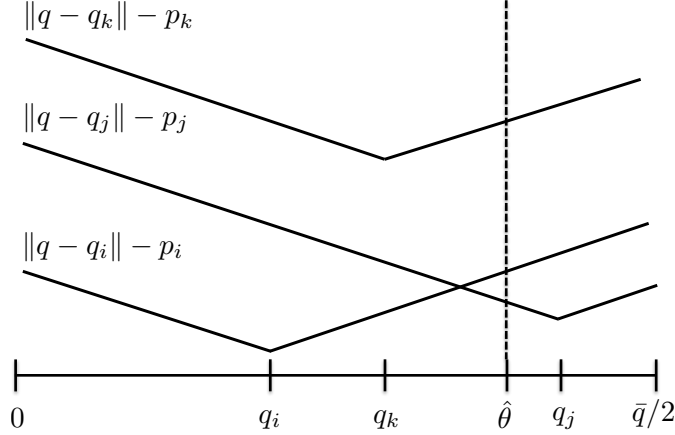


FIGURE 1. *With the appropriate choice of  $\hat{\theta}$  the agent can declare seller  $j$  as the winning seller.*

Figure 1). If at the end of the process, the agent announces the depicted  $\hat{\theta}$  as the buyer’s preferred specification, he can claim that seller  $j$  has the best offer. However, there is no announcement of  $\hat{\theta}$  such that the agent can claim that seller  $k$  has the best offer without violating the public scrutiny constraint.

### 3. EQUILIBRIUM ALLOCATIONS

**3.1. Equilibrium allocation in the auction.** To analyze the auction, we use the revelation principle and restrict our attention to direct revelation mechanisms  $(g, t)$ . At this  $g_i(\hat{\theta}, \mathbf{c})$  denotes the awarding rule — the probability of winning the project for firm  $i$ ;  $t_i(\hat{\theta}, \mathbf{c})$  denotes the transfer to firm  $i$  if the vector of announced costs is  $\mathbf{c} = (c_1, \dots, c_N)$  and the agent sets  $\hat{\theta}$ .

**Lemma 1.** *In any incentive compatible and individually rational direct mechanism,  $\mathbb{E}_{c_{-i}} [g_i(\hat{\theta}, c_i, c_{-i})]$  is decreasing in  $c_i$ .*

The expected surplus of seller  $i$  is given by

$$(1) \quad U_i(c_i) = U_i(\bar{c}) + \int_{c_i}^{\bar{c}} \int g_i(\hat{\theta}, s, \mathbf{c}_{-i}) dF^{N-1}(c_{-i}) ds \geq 0.$$

The expected social surplus is given by

$$(2) \quad \mathbb{E}_{(\theta, \mathbf{c})} \left[ \sum_{i=1}^N g_i(\hat{\theta}, \mathbf{c}) (V - \|\theta - q_i\| - c_i) \right].$$

The expected profit of the buyer is given by

$$(3) \quad \mathbb{E}_{(\theta, \mathbf{c})} \left[ \sum_{i=1}^N g_i(\hat{\theta}, \mathbf{c}) \left( V - \|\theta - q_i\| - c_i - \frac{F(c_i)}{f(c_i)} \right) \right] - \sum_{i=1}^N U_i(\bar{c}).$$

*Proof.* Immediate from Krishna (2009, p. 70) or Naegelen (2002).  $\square$

Thus, the social-surplus optimal and the buyer-surplus optimal auction for a given specification  $\hat{\theta}$  can be described as follows:

**Proposition 1.** *A social-surplus optimal auction for a given  $\hat{\theta}$  is fully characterized by the following awarding rule:*

$$(4) \quad g_i^s(\hat{\theta}, \mathbf{c}) = \begin{cases} 1 & V - c_i - \|q_i - \hat{\theta}\| > V - c_j - \|q_j - \hat{\theta}\| \quad \forall j \neq i \\ 0 & \text{otherwise} \end{cases}.$$

*A buyer-surplus optimal auction for a given  $\hat{\theta}$  is fully characterized by  $U_i(\bar{c}) = 0$  and the following awarding rule.<sup>18</sup>*

$$(5) \quad g_i^b(\hat{\theta}, \mathbf{c}) = \begin{cases} 1 & V - c_i - \|q_i - \hat{\theta}\| - \frac{F(c_i)}{f(c_i)} > V - c_j - \|q_j - \hat{\theta}\| - \frac{F(c_j)}{f(c_j)} \quad \forall j \neq i \\ 0 & \text{otherwise} \end{cases}.$$

*Proof.* Immediate from Krishna (2009, p. 70) or Naegelen (2002).  $\square$

Sellers with a specification  $q_i$  that is close to  $\hat{\theta}$  have a relative advantage. If, all sellers are treated equally, those sellers would bid less aggressively and thereby lower the buyer surplus. Hence, the buyer-surplus optimal awarding rule discriminates against those sellers and thereby triggers more aggressive bidding.<sup>19</sup> Both auctions can be implemented as a first- or second-score auction.<sup>20</sup> Hence, it is meaningful to speak about auctions in the context of this paper.

From expression (1) it follows that maximizing the expected surplus of seller 1 is equivalent to maximizing his winning probability. It is easy to see that in both auctions the winning probability of seller 1 is maximized for  $\hat{\theta} = q_1$ .

**Corollary 1.** *In both, the social-surplus optimal auction as well as the buyer-surplus optimal auction, the agent will set  $\hat{\theta} = q_1$ .*

Thus, the equilibrium allocation of the auction is fully characterized by Corollary 1 and Proposition 1.

<sup>18</sup>To economize on notation we omit the cases  $V - c_i - \|q_i - \hat{\theta}\| = \max_{j \neq i} V - c_j - \|q_j - \hat{\theta}\|$  and  $V - c_i - \|q_i - \hat{\theta}\| - F(c_i)/f(c_i) = \max_{j \neq i} V - c_j - \|q_j - \hat{\theta}\| - F(c_j)/f(c_j)$  as this are probability zero events.

<sup>19</sup>To illustrate this discrimination, suppose that  $F(c) = c$  and  $N = 2$ . In the buyer-surplus optimal auction, seller 1 wins whenever  $2c_i + \|q_i - \hat{\theta}\| < 2c_j + \|q_j - \hat{\theta}\|$ , whereas in the social-surplus optimal auction, seller 1 wins whenever  $c_i + \|q_i - \hat{\theta}\| < c_j + \|q_j - \hat{\theta}\|$ . Thus, in the buyer-surplus optimal auction, the specification advantage has less weight than the cost advantage.

<sup>20</sup>See Naegelen (2002) for details.

**3.2. Equilibrium allocation in the negotiation.** Although we do not put any constraint on how the negotiation is conducted, the two public scrutiny requirements and the assumption that the agent can commit to reject offers, allows us to derive the allocation of the negotiation. This is done by deriving necessary properties of equilibrium allocations for any negotiation protocol that is consistent with the description in Section 2. We proceed in four steps:

(i) *For all honest sellers it is dominated not to lower their offer as long as their offer is above marginal cost and get rejected.* To see this observe that a honest seller whose offer was rejected has no chance to win the project if she does not make a new, lower offer. As long as  $p_i^t > c_i$ , by submitting a lower offer, the seller receives an expected surplus of at least zero.<sup>21</sup> Hence, if  $p_i^t$  has been rejected and  $p_i^t > c_i$ , not submitting a new offer is weakly dominated by lowering  $p_i^t$ . If, contrary to that,  $p_i^t < c_i$  and the seller receives the project, the surplus of this seller will be negative. Thus, if  $p_i^t = c_i$ , lowering  $p_i^t$  is weakly dominated by not submitting a new offer.

(ii) *For any final  $\hat{\theta}$ , the project is awarded to the seller  $i$  whose cost and specification maximize  $V - \|\hat{\theta} - q_i\| - c_i$ .* From property (i) it follows that if seller  $i \neq 1$  exists, she exits at prices equal to his costs. Similarly, seller 1 would only exit if she needs to bid a price below his costs. Now, public scrutiny implies that in order for seller  $j$  to win in the final round  $\tau$ ,  $V - \|\hat{\theta} - q_j\| - p_j^\tau \geq \max_{j \neq i} (V - \|\hat{\theta} - q_j\| - \min_{t \leq \tau} p_j^t)$  has to hold if the agent sets  $\hat{\theta}$  as the final specification. Thus, in order to win, any seller  $i$  (including seller 1) has to submit an offer such that  $V - \|\hat{\theta} - q_i\| - p_i^\tau \geq \max_{j \neq i} V - \|\hat{\theta} - q_j\| - c_j$ . As winning is only favorable if  $p_i^\tau \geq c_i$  the cost and quality parameter of the winning seller must maximize  $V - \|\hat{\theta} - q_i\| - c_i$ .

We summarize properties (i) and (ii) in the following proposition.

**Proposition 2.** *In any equilibrium of the negotiation in undominated strategies each seller  $i$  will resubmit a new, lower offer if his offer is rejected or leave the negotiation whenever  $p_i^t \leq c_i$ . Thus, for any final  $\hat{\theta} \in [0, \bar{q}]$ , seller  $i$  wins the project iff  $V - \|\hat{\theta} - q_i\| - c_i \geq \max_{j \neq i} (V - \|\hat{\theta} - q_j\| - c_j)$ .*

Hence, any equilibrium in undominated strategies of the negotiation is efficient in the following sense: Given a final  $\hat{\theta}$ , the negotiation selects the seller who maximizes the overall surplus at specification  $\hat{\theta}$ . However,  $\hat{\theta}$  might be chosen inefficiently by the agent.

(iii) *The agent will set  $\hat{\theta} = \theta$  whenever seller 1 fails to win the project.* The agent has two objectives when maximizing the joint surplus of him and seller 1. First, seller 1 should receive the project whenever her offer is the lowest offer for some specification  $\hat{\theta}$ . Second, whenever seller 1 fails to win the project the agent has a weak preference for honesty and prefers to set the true

<sup>21</sup>The surplus is strictly positive if the negotiation stops at a price  $p_i^t > c_i$ .

specification. As we have shown above (Proposition 2), the honest bidders will lower their offers to marginal costs if their offers are rejected. Hence, whether seller 1 can underbid the lowest offer of the honest sellers and receive the project is independent of the rejection strategy of the agent. Thus, it comes without a cost to reject offers of honest bidders based on the true specification  $\theta$ , i.e., reject all offers but the offer  $p_i^t$  that maximizes  $V - \|\theta - q_i\| - p_i^t$ . In addition, not rejecting the lowest offer at the true specification has the advantage that whenever the agent realizes that seller 1 cannot profitably win the project, he awards the project to the seller whose offer maximizes the surplus of the buyer for his true specification.

(iv) *The agent will set  $\hat{\theta} = q_1$  if seller 1 wins the project.* This follows directly from what has been said before: seller 1 will win the project if she can underbid all other sellers at some  $\hat{\theta}$ . Seller 1, as she can always observe all offers, then receives a price  $p_1^\tau$  such that  $p_1^\tau + \|q_1 - \hat{\theta}\| = \min_{i \neq 1} p_i^\tau + \|q_i - \hat{\theta}\|$ . This is maximized for  $\hat{\theta} = q_1$ . The following proposition summarizes the equilibrium behavior of the agent.

**Proposition 3.** *The following strategies maximize the surplus of seller 1 and the agent.*

**Strategy of seller 1:**

- (i) *If  $c_1 \leq \min_{i \neq 1} p_i^t + \|q_i - q_1\|$ , seller 1 bids  $p_1^t = \min_{i \neq 1} p_i^t + \|q_i - q_1\|$  and stays in the negotiation.*
- (ii) *Otherwise, seller 1 leaves the negotiation.*

**Strategy of the agent:**

- (i) *If exactly one honest seller is active and seller 1 has submitted an offer, the agent rejects the offer of the honest seller.<sup>22</sup>*
- (ii) *Otherwise, the agent rejects all offers but one of the offers  $j \in \arg \max_{i \neq 1} V - \|q_i - \theta\| - p_i^t$ .*

*If at the end of the process seller 1 is the last active seller, the agent sets  $\hat{\theta} = q_1$ . Otherwise the agent sets  $\hat{\theta} = \theta$ .*

To illustrate the results of Proposition 3, we define and solve a specific negotiation game in Appendix A. Combining Proposition 3 with Proposition 2 yields the equilibrium outcome of the negotiation in terms of an awarding rule of a direct revelation mechanism:

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<sup>22</sup>We call sellers active in round  $t$  if they have not been excluded from the negotiation in previous rounds.

**Corollary 2.** *The equilibrium outcome of the negotiation is equivalent to the outcome of a direct revelation mechanism characterized by the following awarding rule:*

$$(6) \quad g_1^n(\hat{\theta}, c) = \begin{cases} 1 & c_1 \leq \min_{j \neq 1} c_j + \|q_j - q_1\| \\ 0 & \text{otherwise} \end{cases}$$

$$(7) \quad g_i^n(\hat{\theta}, c) = \begin{cases} 1 & c_i + \|q_i - \theta\| \leq \min_{j \neq i} \{c_j + \|q_j - \theta\|\} \\ & \text{and } \min_{j \neq 1} \{c_j + \|q_1 - q_j\|\} < c_1, \quad i \neq 1 \\ 0 & \text{otherwise} \end{cases}$$

#### 4. SOCIAL SURPLUS AND BUYER SURPLUS

**4.1. Social Surplus.** If the buyer is concerned with social surplus, the social-surplus optimal auction for  $\hat{\theta} = q_1$  will be implemented. In this case the social surplus in the negotiation is at least as high as the social surplus in the auction for any parameter constellation. This is due to the fact that in the auction the allocation is distorted for all sellers, as the agent publicly sets  $\hat{\theta} = q_1$  before the start of the auction. Thus, even if seller 1 fails to win the project, the project is not necessarily allocated to the seller that maximizes social-surplus. In the negotiation, however, whenever seller 1 fails to win the project, the agent sets  $\hat{\theta} = \theta$  and the project is allocated to the seller that maximizes social surplus. As the winning probability for seller 1 is the same in both formats, the only difference in social surplus between the auction and the negotiation arises when the object is not allocated to seller 1.

**Proposition 4.** *The negotiation yields a higher social surplus than the auction.*

*Proof.* The proof is relegated to the appendix. □

**4.2. Buyer Surplus.** If  $N = 2$  the buyer-surplus optimal auction yields a higher surplus than the negotiation. This is due to the fact that with two bidders, buyer surplus solely depends on how often seller 1 receives the project compared to seller 2. Both mechanisms allocate the project more often than optimal to seller 1. However, as argued in Section 3, the auction discriminates against the specification advantage gained by manipulation. Thus, the optimal awarding rule is less distorted in the auction than in the negotiation and the auction yields a higher buyer surplus.

**Proposition 5.** *If  $N = 2$  the auction yields a higher buyer surplus than the negotiation.*

*Proof.* The proof is relegated to the appendix. □

If more than two sellers are involved, buyer surplus does not only depend on how often seller 1 receives the project but also on how the project is allocated among the honest sellers. In the negotiation, if seller 1 fails to win, the allocation among the honest sellers will be efficient with respect to the preferred specification of the buyer  $\theta$ . Hence, the loss of buyer-surplus that is due to misspecification is minimized in this case. In the auction, the allocation is distorted not only for seller 1 but also among all other sellers. Thus, the final allocation is independent of the preferred  $\theta$  and may yield allocations with low buyer surplus due to misspecification. The ranking of both formats in terms of buyer surplus then depends on the manipulation probability in the negotiation and the amount of distortion of the optimal allocation in the auction. Both the manipulation probability and the amount of distortion depend on  $\mathbf{q} = (q_1, \dots, q_N)$  in the following sense:

**Lemma 2.** *For every  $N > 2$  there exists  $\bar{q}$ ,  $\theta$ , and*

- (i)  $\mathbf{q}^a$  such that the auction generates a higher buyer surplus;*
- (ii)  $\mathbf{q}^n$  such that the negotiation generates a higher buyer surplus.*

*Proof.* The proof is relegated to the appendix. □

On the one hand, if the distance between the specification of the favorite seller and the preferred specification of the buyer is rather large and the distance between the specifications of the honest sellers is rather small, the auction yields a higher buyer surplus. This is due to the fact that in this case the probability of manipulation in the negotiation is rather large and the distortion of allocation among the honest sellers in the auction is rather small. On the other hand, if the specifications of all sellers are sufficiently dispersed, then the probability of manipulation in the negotiation is rather small and the distortion of the allocation in the auction is rather large. In this case, the negotiation yields a higher buyer surplus.

For a meaningful comparison of both mechanisms along the specification space, we make the following assumption that is common in models of horizontal differentiation on a circle and rules out extreme specification vectors  $\mathbf{q}$ .

**Assumption 2.** *The sellers are located equidistantly along the circle, i.e.,  $\mathbf{q} = (0, 1/N, \dots, (N - 1)/N)$ .*

If Assumption 2 holds true, there exists a lower bound on the number of sellers such that the negotiation yields a higher buyer surplus than the auction:

**Proposition 6.** *If Assumption 2 holds true, there exists  $\bar{N}$  such that the negotiation yields a higher buyer surplus than the auction for all  $N \geq \bar{N}$ .*

*Proof.* The proof is relegated to the appendix. □

If the number of sellers increases, there are two effects that work both in favor of the negotiation. First, manipulation in the negotiation becomes less likely and the negotiation allocates efficiently. Second, the difference in buyer surplus between the efficient and the buyer-surplus optimal allocation decreases. Thus, if the number of sellers becomes large, the negotiation converges to the fully efficient outcome which in this case is also close to the buyer-surplus optimal outcome. The auction remains inefficient even for large  $N$  as the winners of the auction will have specifications close to  $q_1$  instead of  $\theta$ . Hence, the negotiation yields a higher buyer surplus.

## 5. EXTENSIONS

**5.1. The optimal mechanism.** In this section we derive the optimal mechanism given that the buyer is aware of potential manipulation and includes the incentives of the agent in his maximization problem. We continue to use the notation from Section 3 and denote by  $t_0(\theta, \mathbf{c})$  the transfer to the agent in a direct mechanism. We start to characterize the social-surplus optimal and the buyer-surplus optimal mechanism by establishing the following lemma:<sup>23</sup>

**Lemma 3.** *In any incentive compatible mechanism  $(g, t)$ , the winning probability of seller 1,  $g_1(\theta, \mathbf{c})$ , is independent of  $\theta$ .*

*Proof.* The proof is relegated to the appendix. □

The agent maximizes the joint surplus of seller 1 and himself. As  $\theta$  only enters the buyer's surplus but neither the surplus of seller 1 nor of the agent, the optimization problem of the agent is independent of  $\theta$ . Thus, to induce truthful revelation, seller 1 should not benefit from any report of the agent. In this case the agent has a weak preference for honesty and reveals the true  $\theta$ . The optimal auctions can be described as follows:

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<sup>23</sup>Throughout this section we will assume that the agent knows the cost  $c_1$  of seller 1. Otherwise, full surplus extraction is possible from seller 1 by asking the agent to pay a participation fee for seller 1. The optimal fee would then amount to the expected surplus of seller 1 in the subsequent mechanism conditional on the agents report of  $\theta$ . As than seller 1 receives an expected surplus of 0 in either mechanism, the agent reports  $\theta$  truthfully and the optimal mechanism for the other sellers can be implemented.

**Proposition 7.** *The social-surplus optimal auction is given by*

$$g_1^{so}(\theta, \mathbf{c}) = \begin{cases} 1 & \mathbf{E}_\theta [c_1 + \|q_1 - \theta\|] < \mathbf{E}_\theta [\min_{j \neq 1} c_j + \|q_j - \theta\|] \\ 0 & \text{otherwise} \end{cases}$$

$$g_i^{so}(\theta, \mathbf{c}) = \begin{cases} 1 & c_i + \|q_i - \theta\| > c_j + \|q_j - \theta\| \quad \forall j \notin \{1, i\} \\ & \text{and } \mathbf{E}_\theta [c_1 + \|q_1 - \theta\|] > \mathbf{E}_\theta [\min_{j \neq 1} c_j + \|q_j - \theta\|] \cdot \\ 0 & \text{otherwise} \end{cases}$$

*The buyer-surplus optimal auction is fully characterized by the following awarding rule:*

$$g_1^{bo}(\theta, \mathbf{c}) = \begin{cases} 1 & \mathbf{E}_\theta \left[ c_1 + \|q_1 - \theta\| + \frac{F(c_1)}{f(c_1)} \right] < \mathbf{E}_\theta \left[ \min_{j \neq 1} c_j + \|q_j - \theta\| + \frac{F(c_j)}{f(c_j)} \right] \\ 0 & \text{otherwise} \end{cases}$$

$$g_i^{bo}(\theta, \mathbf{c}) = \begin{cases} 1 & c_i + \|q_i - \theta\| + \frac{F(c_i)}{f(c_i)} > c_j + \|q_j - \theta\| + \frac{F(c_j)}{f(c_j)} \quad \forall j \notin \{1, i\} \\ & \text{and } \mathbf{E}_\theta \left[ c_1 + \|q_1 - \theta\| + \frac{F(c_1)}{f(c_1)} \right] > \mathbf{E}_\theta \left[ \min_{j \neq 1} c_j + \|q_j - \theta\| + \frac{F(c_j)}{f(c_j)} \right] \cdot \\ 0 & \text{otherwise} \end{cases}$$

*In both cases  $t_0(\theta, \mathbf{c}) = 0$ .*

*Proof.* The proof is relegated to the appendix. □

In the optimal mechanism, all sellers simultaneously report their cost of delivering the project. As the winning probability of seller 1 cannot depend on the report  $\theta$  of the agent, the buyer checks first whether given his beliefs over  $\theta$  the expected (virtual) surplus of seller 1 exceeds the expected maximal (virtual) surplus of the other sellers. If this is the case, seller 1 receives the project. If this is not the case, the agent is asked to report  $\theta$  and the project is awarded to the honest seller who maximizes the (virtual) surplus.

Observe that the optimal mechanism has properties of both the auction and the negotiation. Similar to the auction, the optimal mechanism limits the gains from manipulation to seller 1 by comparing virtual valuations and thus weighting favorable cost more than favorable locations. Similar to the negotiation, whenever seller 1 fails to win the project, the mechanism is not manipulated and the allocation among the honest bidders is not distorted.

**5.2. Bribery.** We relax the assumption that the favorite seller of the agent is exogenously given. We assume that prior to either procurement process all sellers may try to bribe the agent and become the favorite seller. The timing of the resulting bribery contest is as follows:



- (i) The agent privately observes  $\theta$ . Each seller  $i$  observes  $c_i$ .
- (ii) Each seller  $i \in \{1, \dots, N\}$  submits a bribe  $b_i \in [0, \infty)$ .
- (iii) The agent accepts the bribe of seller  $j$  if her bribe is the largest submitted bribe, i.e.,  $b_j \in \max_i b_i$ .<sup>24</sup> Seller  $j$  becomes the favorite seller.
- (iv) One of the auctions or the negotiation proceeds as described in Section 2.

Finding the equilibrium in the general bribery contest is a difficult problem as it involves solving for an asymmetric equilibrium of an auction with externalities. Thus, we resort to Assumption 2 as it ensures a symmetric set-up. In this case, the following proposition establishes that independent of whether the agent has to conduct an auction or may resort to a negotiation, the same seller wins the bribery contest.

**Proposition 8.** *Suppose Assumption 2 holds true. Then, irrespective of whether one of the auctions or the negotiation is implemented after the bribery contest, seller  $i$  wins the bribery contest if  $c_i < \min_{j \neq i} c_j$ .*<sup>25</sup>

*Proof.* The proof is relegated to the appendix. □

If the sellers are symmetric, the expected gain from being the favorite seller and the expected loss from not being the favorite seller conditional on the realized cost is the same for all sellers. The expected gain from being the favorite seller is increasing with decreasing cost of delivering the project in both auctions and the negotiation. Irrespective of whether an auction or the negotiation is used, the seller with the lowest cost gains the most from bribery and thus wins the bribery contest.

From Proposition 8 it follows directly that the difference between all mechanisms vanishes. This is due to the fact that in either mechanism the favorite seller receives a specification advantage over the other sellers. Thus, being the seller with the lowest cost, the winner of the bribery mechanism always wins the project in both auctions and the negotiation. However, as the selection in the bribery contest is independent of the true  $\theta$ , the resulting allocation can be very inefficient and generate suboptimal buyer surplus.

**Corollary 3.** *If all sellers can bribe the agent and Assumption 2 holds true, the social-surplus optimal auctions, the buyer-surplus optimal auction, and the negotiation yield the same social surplus and buyer surplus.*

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<sup>24</sup>If more than one seller submit the largest bribe, the agent picks one of the sellers with the largest bribe at random.

<sup>25</sup>The provided proof can be adjusted to accommodate any anonymous and increasing bribe selection rule, i.e., any rule that selects the seller with the highest bribe irrespective of his identity. Thus, Proposition 8 is independent of the specific modeling of the bribery contest. Moreover, it can be shown that if the agent always accepts a bribe, Proposition 8 is also true for the optimal bribing mechanism.

**5.3. Accepting Offers.** So far we have assumed that the agent can credibly *reject* the offers of the sellers in the negotiation. In this section we will focus on the case where the agent can credibly *accept* offers. Thus, we modify the negotiation procedure from Section 2 by allowing the agent to award the project to one of the sellers after collecting at least one offer from each seller. As the agent — to benefit his preferred seller — always prefers higher offers to lower offers, he will never inform one of the honest sellers before the end of the process whether hers first offer was sufficient to win the project and thereby give her no chance to improve her offer. Hence, essentially, each seller submits exactly one offer and the negotiation takes the following form:

- (i) The agent privately observes  $\theta$ .
- (ii) Each seller  $i$  submits an offer  $p_i$  to the agent.
- (iii) The agent observes the offers and shows them to seller 1. Seller 1 submits an offer  $p_1$ .
- (iv) The agent chooses the winning seller and sets the final specification  $\hat{\theta}$ . The winning seller is paid her offer.

Public scrutiny implies that if seller  $i$  is the winning seller,

$$V - \|\hat{\theta} - q_i\| - p_i \geq \max_{j \neq i} (V - \|\hat{\theta} - q_j\| - p_j)$$

has to hold.

The strategy that maximizes the joint surplus of the agent and seller 1 is straightforward.

**Seller 1:**

- (i) If  $c_1 < \min_{i \neq 1} p_i + \|q_1 - q_i\|$ , offer  $p_1 = p_i + \|q_1 - q_i\|$  for some  $i \in \arg \min_{i \neq 1} p_i + \|q_1 - q_i\|$ .
- (ii) Otherwise, offer  $p_1 = c_1$ .

**Agent:**

- (i) If  $\min_{i \neq 1} p_i + \|q_1 - q_i\| \geq p_1$ , set  $\hat{\theta} = q_1$  and accept the offer of seller 1.
- (ii) Otherwise, set  $\hat{\theta} = \theta$  and accept the offer of a seller  $i \in \arg \min p_i + \|q_1 - \theta\|$ .

For the honest bidders, the problem of choosing an optimal offer is essentially the same as choosing a bid in an asymmetric first-price auction with a stochastic reserve price.<sup>26</sup> An equilibrium for this game is known to exist. However, a closed-form solution for the bidding strategies is hard to derive.

<sup>27</sup>

Nevertheless, due to the fact that in equilibrium  $p_i > c_i$  and the fact that  $p_i$  converges to  $c_i$  if  $N$  goes to infinity, the results from Section 4 remain valid: if  $N$  is small, the negotiation is

<sup>26</sup>The bid of the corrupt seller 1 resembles a stochastic reserve price.

<sup>27</sup>For a proof of equilibrium existence see Athey (2001). The revenue in the case of two sellers was analyzed by Mares and Swinkels (2014).

manipulated with a high probability. As the auction discriminates against the advantage gained from manipulation, the allocation in the auction is less distorted towards seller 1 than in the negotiation. Hence, the auction may outperform the negotiation for small  $N$ . However, under the conditions stated in Assumption 2, if the number of sellers grows, the probability of manipulation in the negotiation goes to zero and its outcome — contrary to the auction — converges to the fully efficient and buyer-surplus optimal outcome. In this case, the negotiation outperforms both auctions in social surplus and buyer surplus. We summarize this finding in the following:

**Corollary 4.** *The negotiation generates a higher social surplus and buyer surplus than the auction if  $N$  is sufficiently large.*

## 6. CONCLUSION

From the point of view of public procurement regulation, our research question can be interpreted as when to apply public scrutiny to a procurement process. Our results imply that scrutiny at an early stage of the process is not always better. If only the outcome of the procurement process is scrutinized (outcome scrutiny), the agent in charge can refrain from manipulation if he realizes that his favorite seller cannot win the project. If the whole process is scrutinized (process scrutiny), the agent optimally manipulates the process independent of the winning probability of his preferred seller. Interestingly, the European procurement regulations impose public scrutiny on the process rather than the outcome (see Footnote 12).

From the point of view of private procurement, our research question might be interpreted as when to involve the engineering department in the procurement process: before or after the prices have been fixed. Typically the engineering department is in charge of setting the specification and has well established ties to the incumbent supplier and thus is often reluctant to a supplier change. Hence, if the specification is set before the prices are fixed, the engineering department will always manipulate the specification to favor the incumbent. If, however, the procurement is based on the expected specification and the engineering department is involved after the prices are fixed, it may refrain from manipulation.

APPENDIX A. SPECIFIC NEGOTIATION GAME

Define a price grid  $P = \{0, \Delta, \dots, k\Delta\}$  with  $\Delta = \bar{c}/k$  for some  $k \in \mathbb{N}$ . Define by  $A_t \subset \{1, \dots, N\}$  the set of bidders that are still active at round  $t$  and set  $A_1 = \{1, \dots, N\}$ . Denote by  $p^t := (p_1^t, \dots, p_N^t)$  the vector of prices offered by the bidders. The negotiation game can then be described as follows:

**Round 1:**

- (i) Each seller  $i \in A_1 \setminus \{1\}$  submits a price  $p_i^1 \in P$  to the agent.
- (ii) The agent and seller 1 observe all offers  $p_i^1$  and seller 1 offers  $p_1^1$ .
- (iii) The agent informs each seller  $i$  whether his offer has been rejected. This is captured in a vector  $r^1$  with  $r_i^1 = 1$  if the offer of seller  $i$  is rejected and  $r_i^1 = 0$  if the offer of seller  $i$  is not rejected.

**Round  $t$ :**

- (i) Each seller  $i \in A_t \setminus \{1\}$  submits a price  $p_i^t \in P$  to the agent subject to  $p_i^t \leq p_i^{t-1}$ . If  $p_i^t = p_i^{t-1}$  and  $r_i^{t-1} = 1$ , then seller  $i$  is removed from  $A_{t+1}$ . For each seller  $i \notin A_t \setminus \{1\}$ , set  $p_i^t = p_i^{t-1}$ .
- (ii) The agent and seller 1 observe all the offers  $p_i^t$  and seller 1 offers  $p_1^t \in P$  or leaves the auction. This is captured in  $r_1^t$  with  $r_1^t = 1$  if seller 1 leaves the auction and  $r_1^t = 0$  otherwise. If seller 1 leaves the auction, she is removed from  $A_{t+1}$ .
- (iii) The agent informs each seller  $i \in A_t \setminus \{1\}$  whether his offer has been rejected. This is captured in a vector  $r^t$  with  $r_i^t = 1$  if the offer of seller  $i$  was rejected and  $r_i^t = 0$  if the offer of seller  $i$  was not rejected.

The game ends in round  $\tau$  if  $|A_\tau| = 1$ . In this case the last active seller is declared the winning seller and is paid  $p_i^\tau = p_i^{\tau-1}$ . The agent sets the final specification  $\hat{\theta} \in [0, \bar{q}]$ . Public scrutiny implies that if seller  $i$  is the winning seller,  $\|q_i - \hat{\theta}\| + p_i^\tau \leq \min_{i \neq j} \|q_j - \hat{\theta}\| + p_j^\tau$  has to hold.<sup>28</sup>

To express equilibrium strategies of the agent and the bidders, some definitions are in order. A history  $h^t$  at stage  $t$  is defined by

$$h^t := (p^1, \dots, p^{t-1}, r^1, \dots, r^{t-1}, A_1, \dots, A_{t-1}).$$

The agent and seller 1 always observe the whole history at stage  $t$ . Any honest seller  $i \in 2, \dots, N$  only observes his private history  $h_i^t := (p_i^1, \dots, p_i^{t-1}, r_i^1, \dots, r_i^{t-1})$  and whether  $i \in A_t$  which can

<sup>28</sup>If the public-scrutiny constraint is violated, a sufficiently large fine is imposed on the agent. Thus, violation of the public-scrutiny constraint can never be part of an equilibrium of the game.

be deducted from  $h_i^t$ . A strategy of the agent is a mapping with  $\sigma_a(h^t) = r^t$  and  $\sigma_a(h^\tau) = \hat{\theta}$ . A strategy of an honest seller  $i \in \{2, \dots, N\}$  is a mapping with  $\sigma_i(c_i, h_i^t) = p_i^t$ . A strategy of seller 1 is a mapping  $\sigma_1(c_1, h^t) = (p_1^t, r_1)$ . Denote by

$$u_i(\sigma_a, \sigma_1, \dots, \sigma_N) = \begin{cases} c_i - p_i & \text{if } i \in A_\tau \\ 0 & \text{otherwise} \end{cases}$$

the surplus of seller  $i$ . The surplus of the agent is identical to the surplus of agent 1 with the exception that the agent weakly prefers not to manipulate the auction if manipulation does not benefit seller 1. In what follows we describe an equilibrium of the previously defined game. In this equilibrium the honest sellers lower their offers by one price step if they are rejected. Honest sellers leave the auction as soon as lowering their offers one more time would result in a price below their marginal costs. Seller 1 observes all offers and submits the highest possible price that allows her to win at some specification as long as this price is above her costs. As long as more than one honest seller is active or if seller 1 has exited the negotiation, the agent rejects the offers of the honest sellers based on the true preference of the buyer. If only one honest seller and seller 1 are active in the negotiation, the agent rejects the offer of the honest seller.

*Claim 1.* The following strategies form an equilibrium of the negotiation game:

(i) Honest sellers:  $\sigma_i^*(h_i^0) = \bar{c}$

$$\sigma_i^*(h_i^t) = \begin{cases} p_i^{t-1} & \text{if } r_i^{t-1} = 0 \text{ or } p_i^{t-1} - \Delta < c_i \\ p_i^{t-1} - \Delta & \text{if } r_i^{t-1} = 1 \text{ and } p_i^{t-1} - \Delta \geq c_i \end{cases}$$

(ii) Seller 1

$$\sigma_1^*(h^t) = \begin{cases} (\min_{i \neq 1} p_i^t + \|q_1 - q_i\|, 0) & \text{if } \min_{i \neq 1} p_i^t + \|q_1 - q_i\| \geq c_1 \\ (c_1, 1) & \text{otherwise} \end{cases}$$

(iii) Agent

$$\sigma_a^*(h^t) = \begin{cases} r_i^t = 0 & \text{if } i = \min_j \arg \min_j p_j^t + \|q_j - \theta\| \text{ and } |A^t \setminus \{1\}| \geq 2 \\ r_i^t = 0 & \text{if } i = \min_j \arg \min_j p_j^t + \|q_j - \theta\| \text{ and } r_1^t = 1 \\ r_i^t = 1 & \text{otherwise} \end{cases},$$

with  $\sigma_a^*(h^\tau) = q_1$  if  $A^\tau = \{1\}$ ,  $\sigma_a^*(h^\tau) = \theta$  otherwise.<sup>29</sup>

<sup>29</sup>To simplify notation we abstract from the fact that  $\min_{i \neq 1} p_i^t + \|q_1 - q_i\|$  may not be an element of the price grid. In this case we assume that seller 1 chooses the next lowest price on the price grid.

*Proof.* We start with the strategies of the honest sellers. Consider some deviation  $\bar{\sigma}_i \neq \sigma_i^*$ . If following  $\bar{\sigma}_i$  implies that seller  $i$  does not win the project, her surplus is 0 which is at least as good as the surplus from following  $\sigma_i^*$ . Thus, suppose following  $\bar{\sigma}_i$  results in winning the object. Observe, that with  $\sigma_i^*$  seller  $i$  obtains the good with probability 1 if the final price is above  $c_i$ . Hence, a profitable deviation  $\bar{\sigma}_i$  cannot result in a higher winning probability. It follows that any profitable deviation must result in a higher final price at some histories. Suppose seller  $i$  wins the project. The strategy of the agent and the other sellers implies that for the final price  $p_i^r + \|q_i - \theta\| \leq \min_{j \neq i} c_j + \|q_j - \theta\|$  and  $p_i^r + \|q_i - q_1\| \leq c_1$  has to hold. Moreover, following  $\sigma_i^*$  implies that  $p_i^r > \min\{c_1 - \|q_i - q_1\|, \min_{j \neq i} c_j + \|q_j - \theta\| - \|q_i - \theta\|\} - \Delta$ . Thus, following  $\sigma_i^*$  yields the highest feasible price on the price grid given the strategies of the agent and the other sellers. Hence, following  $\bar{\sigma}_i$  cannot constitute a strictly profitable deviation from  $\sigma_i^*$ .

Next, we apply the single deviation principle and show that the strategy of seller 1 is optimal given the strategies of the other sellers and the agent. Without loss of generality, we only consider histories in which seller 1 has not left the negotiation in previous rounds.

Case (i):  $h^t$  is such that  $\min_{i \neq 1} p_i^t + \|q_1 - q_i\| \geq c_1$ . If seller 1 drops out, her surplus from the negotiation is 0. Thus, we may consider only deviations from  $\sigma^*$  with  $r_1^t = 0$ . Observe that if  $|A^t \setminus \{1\}| \geq 2$ , the price submitted by seller 1 has no influence on the rejection strategy of the agent or the bidding strategy of the other sellers. Hence, we may restrict our attention to histories with  $|A^t \setminus \{1\}| = 1$ . Suppose seller 1 submits a price  $p \neq \min_{i \neq 1} p_i^t + \|q_1 - q_i\|$ . If the last remaining honest seller drops out, this implies that either seller 1 gets paid less than when following  $\sigma_1^*$  ( $p < \min_{i \neq 1} p_i^t + \|q_1 - q_i\|$ ) or that the final price violates the public-scrutiny constraint ( $(p > \min_{i \neq 1} p_i^t + \|q_1 - q_i\|)$ ). If the last remaining seller does not drop out, the price submitted in round  $t$  has no implications for the action set of round  $t + 1$ . Thus, bidding  $p$  is not a strictly profitable deviation from  $\sigma_1^*$ .

Case (ii):  $h^t$  is such that  $\min_{i \neq 1} p_i^t + \|q_1 - q_i\| < c_1$ . Any deviation that involves  $r_1^t = 1$  yields a surplus of 0 which is the same as the surplus from  $\sigma^*$ . Thus, suppose  $r_1^t = 0$  and some bid  $p$ . If  $p > \min_{i \neq 1} p_i^t + \|q_1 - q_i\|$  and seller 1 wins the project, the final price violates the public-scrutiny constraints. If  $p < \min_{i \neq 1} p_i^t + \|q_1 - q_i\|$ , then  $p < c_1$ . Thus, if seller 1 wins the project, her surplus is negative. Hence, the proposed deviation from  $\sigma_1^*$  is not profitable.

Finally consider the strategy of the agent. The strategy of the honest sellers  $\sigma_i^*$  prescribes that seller  $i$  will remain active as long as  $p_i^t \geq c_i$ . Thus, irrespective of the agent's rejecting strategy, the surplus of seller 1 is at most  $\min_i c_i + \|q_i - q_1\| - c_1$ . Together with the strategy of seller 1  $\sigma_a^*$  achieves that upper bound. Moreover,  $\sigma_a^*$  is defined such that one of the sellers who have submitted

the lowest offer at the true specification  $\theta$  either wins the project or remains active until the last round. Thus, in case seller 1 does not win the project, the agent may set  $\hat{\theta} = \theta$  without violating the public-scrutiny constraints. Thus, there is no strategy that would make seller 1 and the agent better off given the strategies of seller 1 and the honest sellers.  $\square$

## APPENDIX B. PROOFS

### Proof of Proposition 4.

*Proof.* From equation (6) it follows that in the negotiation seller 1 receives the project whenever  $c_1 \leq \min_{j \neq 1} c_j + \|q_j - q_1\|$ . In the auction the agent implements the social-surplus optimal auction given  $\hat{\theta} = q_1$ . From equation (4) it then follows that seller 1 also receives the project whenever  $c_1 \leq \min_{j \neq 1} c_j + \|q_j - q_1\|$ . Thus, the expected social surplus from allocating the project to seller 1 is the same in both formats. Again from equation (6) it follows that whenever seller 1 does not win the project in the negotiation, the project is awarded to the seller  $i$  with  $c_i + \|q_i - \theta\| \leq \min_{j \neq i} \{c_j + \|q_j - \theta\|\}$ . Thus, the allocation of the negotiation is in this case ex-post social-surplus optimal. Hence, the social surplus in the negotiation is at least as high as in the auction.  $\square$

### Proof of Proposition 5.

*Proof.* Without manipulation it is optimal that seller 1 receives the project whenever her virtual surplus  $V - c_1 - \|q_1 - \theta\| - F(c_1)/f(c_1)$  is larger than the virtual surplus of seller 2. As by Assumption 1 the virtual surplus is decreasing in  $c$  and there are only two sellers, it is sufficient to show that in the negotiation seller 1 receives the project more often than in the auction to prove the result. Define  $c_1^a$  as the lowest cost  $c_1$  such that seller 1 receives the project in the auction given  $c_2$ , i.e.,

$$c_1^a = c_2 + \|q_1 - q_2\| + \frac{F(c_2)}{f(c_2)} - \frac{F(c_1^a)}{f(c_1^a)},$$

and  $c_1^n$  as the lowest cost  $c_1$  such that seller 1 receives the project in the negotiation given  $c_2$ , i.e.,

$$c_1^n = c_2 + \|q_1 - q_2\|.$$

As  $c_1^a > c_2$ ,  $F(c_2)/f(c_2) < F(c_1^a)/f(c_1^a)$  by Assumption 1. Thus,  $F(c_2)/f(c_2) - F(c_1^a)/f(c_1^a) < 0$  and  $c_1^n > c_1^a$ .  $\square$

### Proof of Lemma 2.

*Proof.* Ad (i): Let  $q_1^a = 0$  and  $q_i^a = k$  for all  $i \neq 1$ , i.e., all the honest bidders are symmetric. This situation resembles the situation with two bidders and it is sufficient to show that in the negotiation

seller 1 receives the project in more cases than in the negotiation. This is done in exactly the same manner as in Proposition 5.

Ad (ii): Let  $q_1^n = 0$  and  $q_i^n \in \{0, \bar{q}/2\}$  for  $i \neq 1$ . Suppose furthermore that  $\bar{q}/2 \geq \bar{c} + 1/f(\bar{c})$ ,  $\theta = \bar{q}/4$ ,  $|Q_o := \{i : q_i^n = 0, i \neq 1\}| = m \geq 1$  and  $|Q_1 := \{i : q_i^n = \bar{q}/2, i \neq 1\}| = N - m - 1 \geq 1$ . From  $\bar{q} \geq \bar{c} + 1/f(\bar{c})$  it follows that in the auction all bidders  $i \in Q_1$  have a winning probability of 0 and thus are virtually excluded. The auction then yields a revenue equal to  $V - \|\bar{q}/4\|$  minus the second-lowest cost of  $m+1$  sellers. In the negotiation two cases are relevant. First, if  $c_1 \leq \min_{i \in Q_o} c_i$  the negotiation is manipulated and the sellers in  $Q_{\bar{q}}$  are virtually excluded from the negotiation. The negotiation then yields the same revenue as the auction. Second, if  $c_1 > \min_{i \in Q_o} c_i$ , the negotiation is not manipulated, the agent selects the winner based on  $\hat{\theta} = \theta$  and thus the bidders in  $Q_{\bar{q}}$  are not excluded from the negotiation. In this case the negotiation yields a revenue of  $V - \|\bar{q}/4\|$  minus the second-lowest cost of  $N$  sellers. This is in expectation strictly larger than the revenue in the auction. Overall the negotiation yields a higher expected revenue than the auction for all  $N \geq 3$ .  $\square$

**Proof of Proposition 6.**

*Proof.* In the auction the agent sets  $\hat{\theta} = q_1$  independent of  $N$ . Thus, buyer surplus from the auction approaches  $V - \|q_1 - \theta\|$  if the number of bidders is high. Denote by  $\Pi_a(N)$  the buyer surplus from the auction and by  $\Pi_n(N)$  the buyer surplus from the negotiation. It follows that for every  $\epsilon > 0$  there exists  $N_1(\epsilon)$  such that

$$(8) \quad -\epsilon \leq \Pi_a(N) - (V - \|q_1 - \theta\|) \leq \epsilon$$

for all  $N > N_1(\epsilon)$ .

The agent manipulates the negotiation if and only if  $c_1 \leq \min_{i \neq 1} c_i + \|q_i - q_1\|$ . Thus, given Assumption 2, the probability of manipulation is  $\text{Prob}[c_1 \leq \min_{i \neq 1} c_i + \|(i-1)/N\|]$ . It follows that the probability of manipulation in the negotiation converges to 0 if  $N$  increases. If the negotiation is not manipulated, buyer surplus from the negotiation approaches  $V$ . It follows that for every  $\epsilon > 0$  there exists  $N_2(\epsilon)$  such that

$$(9) \quad -\epsilon \leq \Pi_n(N) - V \leq \epsilon$$

for all  $N > N_2(\epsilon)$ . Comparing equation (8) and equation (9) for an appropriate choice of  $\epsilon$  yields

$$\Pi_n(N) > \Pi_a(N)$$

for all  $N > \max\{N_1(\epsilon), N_2(\epsilon)\}$ . Thus, setting  $\bar{N} = \max\{N_1(\epsilon), N_2(\epsilon)\}$  yields the result.  $\square$



**Proof of Lemma 3.**

*Proof.* Incentive compatibility implies that the joint expected surplus of seller 1 and the agent is

$$U_1(\theta, c_1) = \max_{\hat{c}_1, \hat{\theta}} -\mathbf{E} \left[ g_i(\hat{\theta}, \hat{c}_1, \mathbf{c}_{-i}) \right] c_1 + \mathbf{E} \left[ t_1(\hat{\theta}, \hat{c}_1, \mathbf{c}_{-1}) + t_0(\hat{\theta}, \hat{c}_1, \mathbf{c}_{-1}) \right]$$

and that for all  $c_1$ , and  $\hat{c}_1$

$$U_1(\hat{\theta}, \hat{c}_1) \geq U_1(\hat{\theta}, c_1) - \mathbf{E} \left[ g_1(\hat{\theta}, c_1, \mathbf{c}_{-1}) \right] (\hat{c}_1 - c_1).$$

Thus, at every point  $U_1$  is differentiable with respect to  $c_1$ ,

$$\frac{d}{dc_1} U_1(\hat{\theta}, c_1) = -\mathbf{E} \left[ g_1(\hat{\theta}, c_1, \mathbf{c}_{-1}) \right].$$

It follows that

$$U_1(\hat{\theta}, c_1) = U_1(\hat{\theta}, \bar{c}) + \int_{c_1}^{\bar{c}} \int g_1(\hat{\theta}, s, \mathbf{c}_{-1}) dF^{N-1}(\mathbf{c}_{-1}) ds.$$

Hence, the joint maximization problem of the agent and seller 1 reduces to

$$\max_{\hat{\theta}} U_1(\hat{\theta}, c_1) = U_1(\hat{\theta}, \bar{c}) + \int_{c_1}^{\bar{c}} \int g_1(\hat{\theta}, s, \mathbf{c}_{-1}) dF^{N-1}(\mathbf{c}_{-1}) ds.$$

It follows that the optimal report  $\hat{\theta}$  of the agent is independent of the true  $\theta$ . Thus, in order to induce truthful revelation of  $\theta$ , the agent has to be indifferent among all reports  $\hat{\theta}$ . This is the case if and only if  $g_1(\theta, \mathbf{c})$  is independent of  $\theta$ .  $\square$

**Proof of Proposition 7.**

*Proof.* We start by deriving the buyer-surplus optimal auction. From Lemma 1 and incentive compatibility the optimization problem of the buyer is given by

$$\max_g \mathbf{E}_{(\theta, \mathbf{c})} \left[ \sum_{i=1}^N g_i(\theta, \mathbf{c}) \left( V - \|\theta - q_i\| - c_i - \frac{F(c_i)}{f(c_i)} \right) \right] - \sum_{i=1}^N U_i(\bar{c}),$$

subject to  $\mathbf{E}_{c_{-i}} [g_i(\theta, \mathbf{c})]$  is increasing in  $c_i$  and  $U_i(c_i) \geq 0$ . Optimizing pointwise yields that  $U_i(\bar{c}) = 0$  and that the optimal allocation rule is among the rules such that whenever seller 1 fails to win, the project should be awarded to the honest seller that maximizes the virtual buyer surplus, i.e., whenever  $g_1^{so}(\theta, \mathbf{c}) = 0$  it follows that  $g_i^{so}(\theta, \mathbf{c}) = 1$  if

$$V - \|\theta - q_i\| - c_i - \frac{F(c_i)}{f(c_i)} > V - \|\theta - q_j\| - c_j - \frac{F(c_j)}{f(c_j)}, \quad \forall j \notin \{1, i\}$$

and  $g_i^{so}(\theta, \mathbf{c}) = 0$  otherwise. Thus, the optimization problem of the buyer reduces to

$$(10) \quad \max_{g_1} \mathbf{E}_{(\theta, \mathbf{c})} \left[ g_1(\theta, \mathbf{c}) \left( V - \|\theta - q_1\| - c_1 - \frac{F(c_1)}{f(c_1)} \right) \right] \\ + \mathbf{E}_{(\theta, \mathbf{c})} \left[ (1 - g_1(\theta, \mathbf{c})) \max_{i \neq 1} \left( V - \|\theta - q_i\| - c_i - \frac{F(c_i)}{f(c_i)} \right) \right].$$

From Lemma 1 it follows that  $g_1(\theta, \mathbf{c})$  is independent of  $\theta$ . Thus, problem (10) is equivalent to

$$(11) \quad \max_{g_1} \mathbf{E}_c \left[ g_1(\theta, \mathbf{c}) \mathbf{E}_\theta \left[ V - \|\theta - q_1\| - c_1 - \frac{F(c_1)}{f(c_1)} \right] \right] \\ + \mathbf{E}_c \left[ (1 - g_1(\theta, \mathbf{c})) \mathbf{E}_\theta \left[ \max_{i \neq 1} \left( V - \|\theta - q_i\| - c_i - \frac{F(c_i)}{f(c_i)} \right) \right] \right].$$

Again optimizing pointwise yields the result. The proof for the social-surplus optimal auction proceeds in an analogous manner and is therefore omitted.  $\square$

**Proof of Proposition 8.**

*Proof.* The setting at hand is similar to the setting in Jehiel et al. (1999). However, our setting does not fulfill the symmetry assumptions made there. In Jehiel et al. (1999) it is assumed that in expectation each seller should be indifferent when it comes to who of the other sellers receives the project. This is clearly not the case in our setting. Thus, the proof draws on the ideas presented in Jehiel et al. (1999) but is not a direct consequence of their results.

Define

$$V_i^{\{b, s, n\}}(k, c_i) := \int_{c_i}^{\bar{c}} \int g_i^{\{b, s, n\}}(q_{(i+k \pmod{N})}, s, \mathbf{c}_{-i}) dF^{N-1}(\mathbf{c}_{-i}) ds, \text{ for } k \in \{0, \dots, N-1\}$$

as the surplus of seller  $i$  from participating in the subsequent mechanism if the seller that is located  $k$  steps in the clockwise direction along the circle wins the bribery contest.<sup>30</sup> From here on we will suppress the superscript  $\{b, s, n\}$  whenever the results do not depend on the subsequent mechanism. Note that due to Assumption 2,  $V_i(k, c) = V_j(k, c)$  for all  $i, j \in \{1, \dots, N\}$ . Moreover, due to Assumption 1,  $V_i(k, c_i)$  is a strictly monotonic and thus invertible function of  $c_i$ . Thus, a symmetric strategy in the bribery contest can be written as  $\beta(c_i)$ .

Denote by  $W$  the subset of sellers who submitted the largest bribe and by  $|W|$  its corresponding cardinality. The allocation rule of the bribery contest given the bribes of the sellers can be written

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<sup>30</sup>As before the superscript  $s$  denotes the social-surplus optimal auction,  $b$  denotes the buyer-optimal auction and  $n$  stands for the negotiation.

as

$$x_i(b_1, \dots, b_N) = \begin{cases} \frac{1}{|W|} & i \in W \\ 0 & i \notin W \end{cases}.$$

Note that  $x$  is anonymous, i.e.,  $x_i(b_1, \dots, b_i, b_j, \dots, b_N) = x_j(b_1, \dots, b_j, b_i, \dots, b_N)$ . The winning probability of seller  $j \in \{1, \dots, N\}$  from the point of view of seller  $i$  given  $b_i$  in a symmetric equilibrium can be written as

$$p_j^i(b_i) = \int_{c_{-i}} x_j(\beta(c_1), \dots, b_i, \dots, \beta(c_N)) \, dF_{c_{-i}}.$$

*Claim 2.* For any  $i \in \{1, \dots, N\}$ , any bribe  $b$ , and  $j \neq i$ ,

$$p_j^i(b) = \frac{1 - p_i^i(b)}{N - 1} \text{ and } p_i^i(b) = p_1^1(b).$$

*Proof.* To simplify notation we prove the first equation for

$$p_2^1(b_1) = p_3^1(b_1).$$

From anonymity of  $x$  it follows

$$\begin{aligned} p_2^1(b_1) &= \int_{c_{-1}} x_2(b_1, \beta(c_2), \beta(c_3), \dots, \beta(c_N)) \, dF_{c_{-1}} \\ &\quad \int_{c_{-1}} x_3(b_1, \beta(c_3), \beta(c_2), \dots, \beta(c_N)) \, dF_{c_{-1}}. \end{aligned}$$

As  $c_i$  is symmetrically distributed for all  $i$ , it follows

$$\begin{aligned} \int_{c_{-1}} x_3(b_1, \beta(c_3), \beta(c_2), \dots, \beta(c_N)) \, dF_{c_{-1}} &= \\ \int_{c_{-1}} x_3(b_1, \beta(c_2), \beta(c_3), \dots, \beta(c_N)) \, dF_{c_{-1}} &= p_3^1(b_1) := \alpha. \end{aligned}$$

Thus,  $p_i^1(b_1) = \alpha$  for all  $i > 1$ . Since  $\sum_{j=1}^N p_j^1 = 1$ , we must have  $p_1^1(b_1) + (N - 1)\alpha = 1$ ; this shows the first equality. The second equality is shown analogously.  $\square$

From Claim 2 it follows that the expected surplus of seller  $i$  from submitting bribe  $b_i$  can be written as

$$(12) \quad p_i^i(b_i) \left( V_i(0, c_i) - \frac{1}{N-1} \sum_{k=1}^{N-1} V_i(k, c_i) - b_i \right).$$

Define  $\hat{V}_i(c_i) := V_i(0, c_i) - 1/(N - 1) \sum_{k=1}^{N-1} V_i(k, c_i)$ . Note that,

$$\frac{d}{dc_i} \hat{V}_i(c_i) = \int g_i(q_i, c_i, \mathbf{c}_{-i}) dF^{N-1}(\mathbf{c}_{-i}) - \frac{1}{N-1} \sum_{k=1}^{N-1} \int g_i(q_{(i+k \pmod N)}, c_i, \mathbf{c}_{-i}) dF^{N-1}(\mathbf{c}_{-i}).$$

Observe that  $\int g_i(q_{(i+k \pmod N)}, c_i, \mathbf{c}_{-i}) dF^{N-1}(\mathbf{c}_{-i})$  is the winning probability of seller  $i$  in the subsequent mechanism if seller  $k$  is the favorite seller. In any of the subsequent mechanisms, the winning probability of seller  $i$  is maximized whenever she is the favorite seller, i.e.,

$$\int g_i(q_i, c_i, \mathbf{c}_{-i}) dF^{N-1}(\mathbf{c}_{-i}) > \int g_i(q_{(i+k \pmod N)}, c_i, \mathbf{c}_{-i}) dF^{N-1}(\mathbf{c}_{-i}), \forall k > 1.$$

It follows that

$$\frac{d}{dc_i} \hat{V}_i(c_i) < 0.$$

Thus,  $\hat{V}_i(c_i)$  is strictly decreasing in  $c_i$ . Define the probability density  $\hat{f}(\hat{v}) := f(\hat{V}_i^{-1}(\hat{v}))$ , the corresponding distribution function  $\hat{F}(\hat{v})$ , and the bribing strategy  $\hat{\beta}(\hat{v}) := \beta(\hat{V}_i^{-1}(\hat{v}))$ . Suppose that  $\hat{\beta}(\hat{v})$  is increasing in  $\hat{v}$ . It follows that expected surplus of seller  $i$  in a symmetric equilibrium of the bribery contest can be written as

$$\hat{F}^{N-1}(\hat{V}_i(c_i)) \left( \hat{V}_i(c_i) - \hat{\beta}(\hat{V}_i(c_i)) \right).$$

This is the same as the expected surplus from a symmetric first-price auction among sellers with valuations  $\hat{V}_i(c_i)$ . An increasing and symmetric equilibrium for the first-price auction is known to exist.<sup>31</sup> Thus, there exists a symmetric equilibrium of the bribery contest such that the seller with the largest  $\hat{V}_i(c_i)$  is selected as the favorite seller. As  $\hat{V}_i(c_i)$  is decreasing in  $c_i$  irrespective of the subsequent mechanism, the seller  $i$  with the lowest cost  $c_i$  is selected as the favorite seller before any mechanism. □

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<sup>31</sup>See Krishna (2009) for a proof.

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