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Communication of Preferences in Contests for Contracts*

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Abstract

This paper models a contest where several sellers compete for a contract with a single buyer. There are several styles of possible designs with a subset of them preferred by the buyer. We examine what happens when the buyer communicates information about his preferences. If the sellers are unable to change their style, then there is no effect on the welfare of the sellers. If the sellers are able to make adjustments, extra information may either boost or damage the sellers' profits. While the chance that there will be a proposal of a style preferred by the buyer cannot decrease, the buyer's surplus may increase or decrease.

Keywords: Contests, Procurement, Communication

JEL Classification: D44, H57

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1 Introduction

Boeing and Airbus competed for a contract with the US Air Force to supply the next generation of aerial tankers. In this contest, Airbus won since they were able to supply a larger tanker (based upon the Airbus A330). Boeing complained that the contest was unfair since the preferences of the Air Force was not properly communicated (*International Herald Tribune*, 2008).[1,2]

When firms compete for a contract, often there may be many ways for the contract to be fulfilled. The buyer's preferences over design may not be known by the sellers. A seller can expend significant effort trying to obtain a contract only to find out that there really was little chance of winning (such as for geographic reasons).[3] We ask two main questions. First, how does the existence such preferences affect the equilibrium behaviour and profits of the sellers. Second, would communication about these preferences be beneficial or harmful to the sellers.

To answer our questions, we use as a basis an all-pay auction with complete information about the cost of effort, value to winning and number of contestants (see Baye, Kovenock, and de Vries, 1996). However, we modify the model in two important ways. First, a buyer may favor one style of design over another and we introduce incomplete information about this preferred style of the buyer. Second, we allow effort in the contest phase to save in future effort in the contract phase.

This model has many applications. These include design contests such as with marketing

[1] "If they had been transparent and honest, they would have said, 'We want a larger tanker'. We got a raw deal," Representative Norm Dicks, a Boeing ally (IHT, 2008).

[2] After several months, it was decided that the selection process was flawed. Plans are for the procurement contest to be rerun (*New York Times*, 2009).

[3] Part of the inspiration for this paper was from personal experience where significant effort was invested for a research contract. Afterwards, we discovered that it was all for naught due to geographic considerations for which another bidder had an advantage.

and architecture. Information about preferences has been relevant in architecture design contests for well over 100 years. For instance, in 1835, a Royal Commission was formed to select a design to rebuild the Houses of Parliament. The preferred style was specified to be either Gothic or Elizabethan ruling out the then popular styles of Neoclassical and Italianate (see Service, 1979). The model may also be applicable to other contests not involving design such as competitions to hold the Olympics or other sporting events.

There are several related strands of literature. In auctions, there is a literature that examines the incentives for buyers to acquire information, for example, Lee (1985), Cremer and Khalil (1992), Persico (2000), and Bergemann and Välimäki (2002). There are also papers that consider the situation where the seller can affect the information that the buyers receive. These include Milgrom and Weber (1982), Kaplan and Zamir (2000), Bergemann and Pesendorfer (2007) and Eso and Szentes (2007), Gershkov (2009). In procurement, there is an extensive body of economic literature (see McAfee and McMillan, 1988, and Laffont and Tirole, 1993, for overviews). Among this literature are models built specifically to analyze particular problems. One example is Bajari and Tadelis (2001) who analyze the two main types of contracts used in the construction industry. Like Bajari and Tadelis (2001), in this paper we use a specialized structure to analyze the all-pay nature of procurement procedures and how communication affects the equilibrium. In a somewhat related theme to this paper, Ganuza (2007) shows how poor alignment of incentives for the buyer to discover information about the desired design is a possible explanation for cost overruns in procurements. Comparison between Ganuza (2007) and this paper allows interpretation of the communication of information in this paper as choosing when information would become public: before the sellers submit (prepare) bids or after the bid submission and during the selection of the winning proposal. This is reasonable given the all-pay nature of the competition that we study (the gap between these times is non-trivial).[4] This comparison is furthered in the concluding

[4] In addition, the buyer may learn about his preferences from the proposals themselves.

remarks by a single toy model that captures the basic intuition and results of both papers.

The paper takes the following structure. In the next section, we will describe the basic model. In Section 3, we find the equilibrium, describe our results about communication of preferences. In addition, we expand the analysis to cover communication about identity of the sellers. In Section 4, we conclude and discuss further possibilities of research.

2 Model

There is a buyer that is interesting in selecting a design. There are n sellers offering possible designs. Each proposed design has two characteristics: quality and style. We assume that quality is simply the sunk effort x_i put into the proposal from seller i. The style of a proposal from a particular seller is determined from his exogenously-determined, privately-known type. Furthermore, the buyer's preference over styles is unknown to the sellers. Denote $T = \{1, \ldots, t\}$ as the set of styles. Each seller's style is independently and uniformly drawn from this set.

The buyer strictly prefers a design in the set P to one in the set T/P where $P \subseteq T$. When comparing a design within either P or T/P, the buyer looks at the quality of design. This can be represented by the buyer having utility over the accepted proposal $u(x, \tau) : \mathbb{R} \times T \longrightarrow \mathbb{R}$ where x is the effort put into the accepted proposal and τ is the style. For this utility to match the specified environment $u(x, \tau) = x + \rho$, if the proposal τ is from the preferred set ($\tau \in P$), where constant ρ is the premium for a preferred design, and x otherwise ($\tau \in T/P$).[5] (We will discuss shortly the constraint that ρ must be large enough.) The buyer selects his

[5]One can think of a buyer as an agent for procurement and the higher x makes the agent better protected from possible future criticism. Along similar lines, there could be an exogenous chance of the design failing. A higher x may help determine this earlier which may allow the buyer to save time rerunning the contest. We assume the terms of the payments are dictated by an industry standard and hence not a factor in the buyer's utility.

preferred design and in case of indifference chooses randomly. The sellers know only p ($\#P$) and that each style has an equal chance of being in the preferred set.

We assume that once selected, the seller must complete the design. The amount of additional effort needed to complete the design is given by $a(x)$ where $a(x)$ is weakly decreasing in x and weakly positive. This represents the notion that a higher quality proposal will have a lower amount of work needed to complete the project. We also assume that $a'(x) > -1$. This ensures that holding off effort until one gets the contract never costs more ($\gamma = argmin_{x \geq \gamma} x + a(x)$ for all $\gamma \geq 0$, procrastinate if one can). Finally, the seller with the winning design gets a reward (prize) worth V (there is some industry standard or regulation keeping the prize fixed). To avoid a trivial solution, we assume that $V > a(0)$. We have the additional constraint that $\rho > \max\{z|\ z \leq V - a(z)\}$. This ensures that the premium ρ is large enough such that in equilibrium the buyer will always strictly prefer a proposal in P over a proposal in T/P.[6,7]

[6] The buyer prefers a incomplete design with effort x_1 in the preferred set to a more complete design with effort x_2 that is not in the preferred set. We must have $x_2 < \rho$, since if $x_2 \geq \rho$, seller 2 would not make a profit even if he wins since our assumption on ρ implies $V - a(x_2) - x_2 < 0$. Since $x_2 < \rho$, we have $x_1 + \rho > x_2$.

[7] We assume the buyer must select one of the proposals. Results should hold if the preferred designs are the only ones that are selected. This may happen in some cases. For instance, in 1850, a Royal Commission was formed to select a design for the Great Exhibition. Despite that 245 plans were submitted, none were selected. The selection committee (which included Barry and Brunel) substituted their own design. Fortunately, they realized the weakness in design by committee and convinced Joseph Paxton to submit plans, creating the Crystal Palace (see Beaver, 1970).

3 Results

3.1 Equilibrium

We look for an equilibrium which is denoted by an n-tuple of cumulative distribution functions, CDFs, $F_i(x)$, where each seller i puts forth effort x_i according to the CDF $F_i(x)$, and given that the other sellers do the same, each seller has no incentive to deviate. (Note a pure strategy at x^* can be represented by $F_i(x) = 0$ for $x \leq x^*$ and $F_i(x) = 1$ for $x > x^*$.)

Lemma 1 *In any equilibrium, the expected profit of a seller equals* $\pi(n, \frac{p}{t}) \equiv (\frac{p}{t}) \cdot (1 - \frac{p}{t})^{n-1}(V - a(0))$.

Proof. In the Appendix. ■

We make use of Lemma 1 to derive the equilibrium and show that it is unique as long as the preferred set is not trivial (neither equal to T nor empty).

Proposition 1 *If $P \neq T$ and $P \neq \varnothing$, then the equilibrium is unique where all sellers use the same CDF equal to F where F satisfies the following equation:*

$$(V - a(x)) \left[(1 - \frac{p}{t})^n F(x)^{n-1} + \sum_{m=0}^{n-1} \left(\begin{array}{c} n-1 \\ m \end{array} \right) (\frac{p}{t})^{m+1} (1 - \frac{p}{t})^{n-1-m} F(x)^m \right] - x = \pi(n, \frac{p}{t}). \tag{1}$$

If $P = T$ or $P = \varnothing$, any equilibrium will have $m \geq 2$ sellers actively bidding and $n - m$ sellers always choosing 0. All active sellers will use the same CDF equal to F where F solves.

$$(V - a(x))F(x)^{m-1} - x = 0.$$

Proof. In the Appendix. ■

This uniqueness is unusual compared to the more standard all-pay auctions with complete information where there are multiple equilibria (see Kaplan, Luski and Wettstein, 2003). For instance, take a standard all-pay auction with three bidders and a prize worth 1. There is an equilibrium with all three bidders using $F_i(x) = \sqrt{x}$. There is also an equilibrium with one bidder i always choosing 0 and the other two bidders choosing $F_j(x) = x$ (where $j \neq i$).

Now let us look at an example to further understand the mixed-strategy equilibrium.

Example 1 *$n = 2$, $V = 2$, $a(x) = 1 - x/2$, $t = 2$, $p = 1$.*

Here the profit would be $\pi(n, \frac{p}{t}) = \pi(2, \frac{1}{2}) = (\frac{p}{t}) \cdot (1 - \frac{p}{t})^{n-1}(V - a(0)) = (\frac{1}{2}) \cdot (1 - \frac{1}{2})(2 - 1) = \frac{1}{4}$. Using equation (1), the equilibrium distribution function is given by $(1 + \frac{x}{2})\left[(1/2)F(x) + 1/4\right] - x = \frac{1}{4}$, which implies

$$F(x) = 2\left(\frac{2x + 1/2}{x + 2} - \frac{1}{4}\right) = \frac{7x}{2x + 4}.$$

Notice that the top bid a seller will place is at $x = 4/5$. Thus, for the buyer to prefer a bid of 0 in the preferred set to a bid of 4/5 in the non-preferred set, we must have $\rho > 4/5$. We assumed that $\rho > \max\{z|\ a(z) + z \leq V\} = \max\{z|\ 1 + z/2 \leq 2\} = 2$, so this is satisfied. ■

3.2 Communication

In the auction literature, Milgrom and Weber (1982) show when values are affiliated, a seller should always release information. This would increase the seller's profits and hurt the buyers' profits. Gershkov (2009) shows the optimal auction involves full disclosure when values are a combination of private and common values. On the other hand. Kaplan and Zamir (2000) show in a particular auction design partial information release could be optimal. In our framework, we deal with a similar question about the release of information. The notable difference (besides reversing the buyer's and sellers' roles) is that here the buyer is choosing between potentially heterogeneous objects and the information is about the differences in the values of these objects to the buyer rather than information about the costs of a single object to the sellers.

More specifically, in our model, the information that the buyer possesses is about his preferences for the various contracts. In many cases, he may only learn his complete preferences after the proposals are offered or they may be expensive to learn beforehand. This may very well be the case with architecture contests, but it is quite possible that he may know his preferences partially before as in the case with Boeing and Airbus. For example, take a university holding a competition for a building design. The university may have preferences about the arrangement of offices and know this beforehand. For instance, the university may prefer offices be built around an open atrium over being built in more secluded hallways. Because of this, information released may affect the sellers' belief over which type of office arrangement is preferred.

As we see from the university example, architecture firms may be able to submit a proposal that is contingent on the information released. In the competition to rebuild the Houses of Parliament, the winner out of 97 proposals, Charles Barry, was known for his Italianate style, but for the competition he was able to switch to a Gothic design. In the case of Boeing versus Airbus, the contest will be rerun with the additional information about the Air Force's preferences. Boeing plans to switch to a design based upon the larger 777 from the smaller 767 (*New York Times*, 2009). This would match the size of the current Airbus proposal. However, Boeing would not be able to match a proposal (in size of aircraft) if Airbus based its plans on the new A380.

The buyer releases information by sending a signal $s \in S$ that depends upon his preferences; namely, a function $g : \mathbb{P} \to \Delta(S)$, where $\mathbb{P} = \{P \subseteq T : \#P = p\}$. The way that information is released, the g used by the buyer, is known to the sellers in advance. They then use Bayes rule to infer likelihood of each possible set of preferred styles and in particular, the likelihood that they are in that set. Not releasing information is equivalent to sending the same signal for each possible preferences: using a function such as $g(P) = s_1$ for all $P \in \mathbb{P}$. The g function can also incorporate cases where the buyer does not fully learn his preferences beforehand. For instance if $T = \{1, 2, 3\}$, $p = 1$ and the buyer cannot distinguish between $P = \{1\}$ and $P = \{2\}$ but can between $P = \{3\}$ and $P = \{1\}$ (and between $P = \{3\}$ and

$P = \{2\}$), then we are constrained by $g(\{1\}) = g(\{2\})$, but can have $g(\{3\}) \neq g(\{1\})$.

To begin to examine the effect of a release of information, we must first under what case, the sellers' profits are maximized. We do so in the following lemma.

Lemma 2 *Given there are n sellers, the sellers' profits are maximized when $\frac{p}{t} = \frac{1}{n}$.*

Proof. Denote $\frac{p}{t}$ as f. We have $\pi(n, f) = f \cdot (1-f)^{n-1}(V - a(0))$. The first-order condition with respect to f is $(1-f)^{n-1} = (n-1) \cdot f(1-f)^{n-2}$. Solving yields $f = 1/n$. Note that $\pi_{ff} \leq 0$ ($\pi_{ff} < 0$ for interior f) so the second-order condition is satisfied. ■

Note that a $\frac{p}{t}$ that is too low makes is very unlikely that any seller's style will be in the preferred set. A $\frac{p}{t}$ that is too high will make it too likely that two or more sellers will have a style in the preferred set. When $\frac{p}{t} = \frac{1}{n}$, the balance between these two forces is at an optimal. We can make use of the above lemma and see, for one, if it would ever improve sellers' profits to communicate information about a buyer's preferences.

Proposition 2 *(i) If the sellers are unable to change their style, then communicating information about preferences will have no effect on sellers' expected profits nor the chance of the winning proposal's style being in the buyer's preferred set, but it may increase or lower the buyer's expected surplus.*
(ii) If the sellers can change their style, then communicating information about preferences would always increase the chance the winning proposal will be in the preferred set, but is sometimes beneficial and sometimes damaging to the sellers and buyer.

Proof. In the Appendix. ■

We see from the Proposition that the release of information about preferences can have different effects on the sellers' profits. This for the most part depends upon the flexibility of the sellers, the number of sellers, and the refineness of information released. If firms are fully flexible and the information fully reveals P, then the information will only hurt the sellers.

Likewise, if $\frac{p}{t} \geq \frac{1}{n}$, then extra information will only hurt sellers (it will effectively reduce t). On the other hand, if $\frac{p}{t} < \frac{1}{n}$, then the chance of a seller being a unique seller in the preferred set is too small for maximal profits. The release of either a small amount of information or a limited amount of flexibility will increase $\frac{p}{t}$ to a more desirable level.

Example 2 *$n = 2$, $V = 2$, $a(x) = 1 - x/2$, $T = \{1,2\}$, $\mathbb{P} = \{\{1\},\{2\}\}$, $S = \{1,2\}$, $g(\{1\}) = 1$, $g(\{2\}) = 2$.*

Let us first look at the case when sellers cannot change style. With this g, the information sent allows the seller knows whether or not he is in the preferred set. If the seller is in P, then there is a 1/2 chance that the other seller is in P/T. Denote the strategy of a seller with a style in P as F^p and the strategy of a seller with a style in P/T as F^{np}. We then have two indifference equations. A seller in P must be indifferent to all strategies in his support. Thus,

$$\left(\frac{1}{2}F^p(x) + \frac{1}{2}\right)(2 - a(x)) - x = \frac{1}{2}.$$

Likewise, if the seller is in P/T, we have

$$\left(\frac{1}{2}F^{np}(x)\right)(2 - a(x)) - x = 0.$$

This yields $F^p(x) = \frac{3x}{2+x}$ and $F^{np}(x) = \frac{4x}{2+x}$. Note the ex-ante expected profit of the sellers is still 1/4 and the equilibrium CDF without information being released is $F(x) = \frac{7x}{4+2x}$.

Now let us look at the case when sellers can costlessly change their styles to any style in T. Here, both sellers will switch to the preferred style. We then have a single indifference condition:

$$F(x)(2 - a(x)) - x = 0.$$

This condition implies $F(x) = \frac{2x}{x+2}$ with ex-ante expected seller profits of 0. ■

We now wish to use an example where depending upon the parameters, a buyer may gain from sending information or not gaining from sending information.

Example 3 *$n = 2$, $V = 2$, $a(x) = 1$, $\# \ \mathbb{P} = \# \ S$, for all $P_1, P_2 \in \mathbb{P}$ if $P_1 \neq P_2$, then $g(P_1) \neq g(P_2)$.*

For this example, the sellers can correctly distinguish the buyer's preferred set but cannot switch styles.

Without information transmitted, i.e., $g(P) = s$ for all $P \in \mathbb{P}$, a seller will use $F(x)$ such that

$$\left(\frac{p}{t}\left(1-\frac{p}{t}\right)+\left(\left(\frac{p}{t}\right)^2+\left(1-\frac{p}{t}\right)^2\right)F(x)\right)-x=\frac{p}{t}\left(1-\frac{p}{t}\right).$$

This implies that

$$F(x)=\frac{x}{\left(\frac{p}{t}\right)^2+\left(1-\frac{p}{t}\right)^2}.$$

The buyer's expected surplus is $2\frac{p}{t}\left(1-\frac{p}{t}\right)\int xdF+\left(\left(\frac{p}{t}\right)^2+\left(1-\frac{p}{t}\right)^2\right)\int xdF^2$. Since F is uniform, we have the buyer's surplus equal to $\frac{p}{t}\left(1-\frac{p}{t}\right)\left(\left(\frac{p}{t}\right)^2+\left(1-\frac{p}{t}\right)^2\right)+\frac{2}{3}\left(\left(\frac{p}{t}\right)^2+\left(1-\frac{p}{t}\right)^2\right)^2$. With information, a seller knows whether he is in the preferred set or not. If he is in the preferred set, a seller will use $F^p(x)$ that solves

$$\left(1-\frac{p}{t}+\left(\frac{p}{t}\right)F^p(x)\right)-x=1-\frac{p}{t}.$$

This implies $F^p(x) = x/(p/t)$. If a seller is not in the preferred set, he will use F^{np} that solves

$$\left(1-\frac{p}{t}\right)F^{np}(x)-x=0.$$

This implies $F^{np}(x) = x/(1-(p/t))$. The buyer's surplus is $2\frac{p}{t}\left(1-\frac{p}{t}\right)\int xdF^p+\left(\frac{p}{t}\right)^2\int xd\left(F^p\right)^2+\left(1-\frac{p}{t}\right)^2\int xd\left(F^{np}\right)^2$. Since both F^p and F^{np} are uniform, this surplus equals $\left(\frac{p}{t}\right)^2\left(1-\frac{p}{t}\right)+\left(\frac{2}{3}\right)\left(\left(\frac{p}{t}\right)^3+\left(1-\frac{p}{t}\right)^3\right)$. There are four solutions to where the two buyer surpluses (with and without information) are equal: $\frac{p}{t} = -1, 0, \frac{1}{2}, 1$. When $\frac{p}{t} = \frac{1}{4}$, without information yields higher surplus. When $\frac{p}{t} = \frac{3}{4}$, with information yields higher surplus. Thus, for $0 < \frac{p}{t} < \frac{1}{2}$, the buyer strictly prefers to withhold information and for $\frac{1}{2} < \frac{p}{t} < 1$, strictly prefers to send information. ■

We see here that the extra information can effect the buyer's expected surplus either way. This happens even when the sellers cannot switch styles and the chance the proposal is in the preferred set is unchanged. In such a case, sellers are not affected in terms of expected profits. The buyer is effected since the buyer cares about the winning effort and while the sellers expected profits are not changed, their strategies are. One note about efficiency. The ambiguity in the buyer's surplus causes the sum of the buyer's expected surplus and the sellers' expected surpluses to also be ambiguous. Thus, it isn't clear which is more efficient.[8]

3.3 Information about the Sellers

Above we assumed that the sellers competing for the contract do not know each other. In many situations, this may very well be the case. In other situations, sellers may know who they are competing against. For instance, the contract selection may be in two stages. In the first stage there is a call to see who is interested. In the second stage, a longer proposal (bid) is required. It is after this first stage that information can be communicated about who is competing.[9] We now analyze the effect of such communication about the identity of the sellers (which would be more pertinent to situations with less sellers).

Before continuing, we need to be more specific about the sellers' types when there is a possibility of changing styles. We define a seller i's type to be a default style t_i and a set of styles T_i to which the seller can costlessly switch to (where $t_i \in T_i \subseteq T$). A seller is unable to change his style if $T_i = \{t_i\}$. Being consistent with the prior sections, we assume that each style has an equal chance of being the default style and there is symmetry with respect to the sets of styles. For example, if there are three styles, two sellers and there is a 1/10 chance

[8] An efficient allocation would have select one seller (first selection from any sellers with a possible style in the preferred set). There will be some optimal level of effort by this selected seller. (To avoid corner solutions, we would either need to make the seller's cost of effort be convex rather than linear or make the buyer's utility of effort be concave in effort.)

[9] It is possible that after the first stage, the competing sellers are invited for a meeting together.

that $T_1 = \{1, 2\}$, then there is also a 1/10 chance of $T_1 = \{1, 3\}$ or $T_1 = \{2, 3\}$. In addition, for seller 2, there would also be a 1/10 chance of T_2 being any of these sets.

Formally, each seller i's set of styles must be drawn from $\mathbb{T}_i \equiv 2^T$ and the set of all possible sellers' types is $\mathbb{T} \equiv T^n \times \mathbb{T}_1 \times \mathbb{T}_2 \ldots \times \mathbb{T}_n$. The probability of each set occurring is given by $\mu : \mathbb{T} \rightarrow \mathbb{R}^+$. For feasibility $\mu(\{t_i, T_i\}) > 0$ only if $t_i \in T_i$ $\forall i$. For symmetry, for any reordering of sellers $o : \{1, \ldots, n\} \rightarrow \{1, \ldots, n\}$, we have $\mu(\{t_i, T_i\}) = \mu\left(\{\widetilde{t}_i, \widetilde{T}_i\}\right)$ if $t_i \in T_i$, $\widetilde{t}_i \in \widetilde{T}_i$ $\forall i$ and $\# T_i = \# \widetilde{T}_{o(i)}$. This setup results in two properties. First, an individual's type is independent of another's individual type. Thus, one infers nothing about the other's types from one's own type. Second, there is an equal chance of all types occurring. This is consistent with the rest of the paper.

Note that without information, there is an equilibrium where all sellers stick with their default style. This is because for each possible style in a seller's choice set, there is an equal chance of another seller having that style as a default. We call this equilibrium, the default equilibrium.

Proposition 3 *(i) If the sellers are unable to change their style, that is, $T_i = \{t_i\}$, then making the sellers' types public information will have no effect on sellers' expected profits nor effect the chance that the winning proposal will be in the preferred set. (ii) If the sellers are able to change their style, the buyer's surplus may increase or decrease. (iii) If there are two sellers and they can change their style, then making the sellers' types public information would increase the sellers' profits compared to those in the default equilibrium.*

Proof. In the Appendix. ■

Example 4 $n = 2$, $V = 2$, $a(x) = 1 - x/2$, $t = 2, p = 1$, $T_i = \{t_i\}$.

Here, the ex-ante profits without information is the same as before: 1/4. When the sellers' identities are disclosed, the expected profit is 0 when $t_1 = t_2$ and 1/2 when $t_1 \neq t_2$. Since each possibility happens half the time, the overall expected profits is 1/4. ■

Example 5 $n = 2,\ V = 2,\ a(x) = 1 - x/2,\ t = 3, p = 1,\ \mu(\{\{1,\{1,2\}\},\{2,\{2,3\}\}) = \mu(\{\{2,\{1,2\}\},\{3,\{2,3\}\}) = \ldots = 1/36$.

The ex-ante expected seller profits without information about the other seller's type is $\frac{1}{3} \cdot \frac{2}{3} = \frac{2}{9}$. Each would use a CDF that satisfies

$$(\frac{2}{9} + \frac{5}{9}F(x))(2 - a(x)) - x = \frac{2}{9}.$$

This implies

$$F(x) = \frac{16x}{10 + 5x}.$$

Now let us look at the equilibrium when all the sellers' types become public knowledge. When $T_1 \neq T_2$, for instance, when $T_1 = \{1,2\}$ and $T_2 = \{2,3\}$. Any equilibrium would have them choosing different styles for their bids. If seller 1 in equilibrium selected style 2 and there was a possibility that seller 2 also would select style 2, then seller 1 can do strictly better by choosing the same effort but style 1. Thus, when $T_1 \neq T_2$, the sellers' choose different styles. Since $p = 1$, there is a 1/3 chance they both will not be in the preferred set. Hence, their indifference condition is

$$\left(\frac{1}{3} + \frac{1}{3}F(x)\right)(2 - a(x)) - x = \frac{1}{3}.$$

This implies

$$F(x) = \frac{5x}{x + 2}.$$

When $T_1 = T_2$, it is an equilibrium for seller i to randomly choose (with equal chance) between the two styles in the set T_i. Doing so will give them 1/2 probability of submitting the same style and 1/6 probability of being unique in the preferred set yielding expected payoff of 1/6. The equilibrium CDF is $F(x) = 11x/(x + 2)$. This equilibrium will yield the lowest payoff. The chance of $T_1 = T_2$ is 1/3. Therefore, the expected profit is $\frac{2}{3} \cdot \frac{1}{3} + \frac{1}{3} \cdot \frac{1}{6} = \frac{5}{18}$. Note that this is still higher than the non-disclosure equilibrium. The equilibrium with the highest payoff would involve everyone choosing a separate style. This yields an expected payoff of 1/3. ■

Proposition 3 is comparable to Proposition 2, but where the potential increase of information is about the sellers' types rather than the buyer's preferences. While the results are similar when the sellers cannot make changes, they differ when the information is about the sellers' types rather than the buyer's preferences. Namely, when sellers can alter their style, communication about the sellers' types helps their profits, but communication about the buyer's preferences can help or hurt sellers' profits. The reason for this is when the information is about types, the sellers want to differentiate themselves, but when it is about the buyer's preferences, they want to increase the likelihood of having a preferred style which may hurt differentiation.

These results should still hold if we adding switching cost to switching styles. Sellers would not be harmed by the communication of information, but now when it is advantageous to switch, the sellers will weigh the gains against the potential cost and thus switch less frequently. Also, if information about the sellers is about the number of sellers competing rather than their types, the situation would be comparable to that where sellers cannot switch styles and such communication will have no effect in expected payoffs.

4 Concluding remarks

In this paper, we considered the case of sellers trying to win a contract with a buyer where a buyer has preferences over styles of designs. Interestingly, while a losing seller may always complain about how the buyer did not properly communicate his preferences, that seller's expected profits ex-ante may have been higher thanks to this lack of communication (as possible in the case when sellers can switch styles).

Although a very different model, Ganuza (2007) presents a case where the release of additional information about the buyer's preferences can be beneficial to the sellers. The extra information creates a local monopoly for a seller whose product is closest to the buyer's preferences.[10] This difference to our model can be explained by the following toy model that combines features of both models. There is a buyer and two sellers: one that sells type A objects and the other of type B objects. With equal probability, the buyer either values object A at v and object B at 0 or values object B at v and object A at 0. A seller can produce the other type of object at cost c otherwise the cost is 0. A buyer can choose to discover his type before issuing the contract. If this type is discovered before, it becomes public information. Otherwise, the type is discovered after the contract is signed but before the work is finished, allowing the seller to switch types at cost c. If the type is discovered before, the buyer with the correct type wins an auction and receives c. The buyer's expected profits is $v - c$. If the type is not discovered, we assume that in the second stage the buyer has bargaining power. In this case, both firms compete away profits and the buyer receives the good for a price of 0. However, there is a 50% chance that the buyer will have to pay c. Thus, his expected profits is $v - \frac{c}{2}$. Hence, the buyer does better without discovering the information. In our model, the buyer knows the information before choosing a contract and can decide whether or not to reveal it to the buyers. In this toy model, not revealing information will change the behavior compared to not having information since the buyer can still make use of this information in selecting a contract. Bidding c is now the equilibrium with the buyer selecting the correct firm. The expected profit of the buyer will be again $v - c$.

We now conclude with several suggestions for future work. One possibility is to have smooth preferences such as in the Hotelling (1929) or Salop (1979) models. This type of

[10] It also leads to the buyer underinvesting in acquiring information and choosing the wrong product more often then in an efficient world. This wrong product choice leads to extra adjustments: overruns.

preference structure was used in the aforementioned Ganuza (2007) model and has promise (though keeping in mind that from the above discussion it is not obvious that the results will change).

One may consider that in the contest stage there is no advantage to design that exceeds the necessary work. In such a case, the c such that $a(c) = 0$ will serve as a bid cap and the buyer will randomly select among those putting effort at the cap. In this case, the equilibrium will be similar to that in Che and Gale (1998). However, Kaplan and Wettstein (2006) give arguments why such a cap should be considered soft as whereby the equilibrium would not qualitatively be different to the one in this paper.

One can also investigate teams of sellers as we see that often in contract contests, parties submit joint bids. Studying such mergers in our framework adds the interesting element that merging lower the chance of having a preferred style. Finally, it would be worthwhile to examine the same issues but with a different foundation for the model. For example, one can model the all-pay auction as one of incomplete information about values or costs of effort as in Amann and Leininger (1996) or using a Tullock (1980), rent-seeking success function.

5 Appendix

Proof of Lemma 1.

We first show that there cannot be an atom (discontinuous jump in F_i) in the mixed strategy equilibrium at any strictly positive point. We show this by contradiction. Denote the probability seller i winning by choosing x as $W_i(x)$. Suppose there is an atom played by seller i at $x^* > 0$. For this to happen, there must be a strictly positive probability of seller i winning at that point, that is, $W_i(x^*) > 0$, since choosing $x^* > 0$ is costly. In addition, choosing any $y < x^*$ must yield a strictly lower probability of winning, $W_i(y) < W_i(x^*)$ for all $y \in [0, x^*)$. This is because from our assumptions on $a(x)$, it pays to procrastinate if it does not hurt one's chance of winning, that is, for any constant $c > 0$, we have $\min_{x\in X} c \cdot (V - a(x)) - x = \min_{x\in X} x$. Since choosing $y < x^*$ yields a lower probability of winning, for any set $X^*(z) \equiv [z, x^*)$ where $z \in [0, x^*)$, there must be some seller j choosing a y in $X^*(z)$ (there exists a j where y is in the support of F_j). However, choosing $x^* + \varepsilon$ will yield a discreet jump in probability of winning for seller j. Thus, for large enough z, we will get a contradiction. (There exists a $z \in [0, x^*)$ and $\varepsilon > x^* - z$ such that $W_j(y)(V - a(y)) - y < W_j(z+\varepsilon)(V - a(z+\varepsilon)) - z + \varepsilon$.)

We now show that if $p/t \in (0, 1)$, seller i cannot be bidding an atom at 0 by way of contradiction. Say that seller i is choosing an atom at 0 of magnitude $m \in (0, 1]$. This implies that $F_i(x) \geq m > 0$ for all $x > 0$. If seller i is the only seller choosing an atom at 0, seller i's profits must be equal to the chance that i is the unique seller in the preferred set times the profit of winning with a zero effort, namely, $(\frac{p}{t}) \cdot (1 - \frac{p}{t})^{n-1}(V - a(0))$. All other sellers can bid ε and obtain profit that approaches $(\frac{p}{t}) \cdot (1 - \frac{p}{t})^{n-1}(V - a(0)) + m(\frac{p}{t})^2 \cdot (1 - \frac{p}{t})^{n-2}(V - a(0))$ as $\varepsilon \to 0$. Since this is a mixed-strategy equilibrium, a seller j is indifferent to bidding between any two points in the support of F_j. Since there are no atoms above zero, seller i can bid at the top of j's support and win with certainty. This should be the same profit that seller j earns since at the top of j's support, seller j also wins with certainty. However, seller j's profits is strictly higher than seller i's profits since p/t is strictly between 0 and 1. Thus, seller i would have incentive to deviate and would not place an atom at 0. If there is more than one seller placing an atom at 0 and p/t is strictly between 0 and 1, then any seller choosing an atom would have incentive to bid ε since the probability of winning will jump discretely.

Now we know that if $p/t \in (0, 1)$, an equilibrium will not contain atoms anywhere. We will now show that zero must be the lowest point in the support of all sellers. Suppose $z_i > 0$ is the lowest point of the support of player i. Let $\underline{z} = min_i \; z_i$. Since in equilibrium there are no atoms, the probability of winning at $\underline{z}$ must be the same as the probability of winning at 0 for all sellers, that is, $W_i(\underline{z}) = W_i(0)$ for all i. The seller j whose support F_j includes $\underline{z}$ also has $W_j(\underline{z}) = W_i(0)$; however, j can then improve profits by choosing 0. Thus, $\underline{z} = 0$.

The probability of j winning by bidding 0, $W_j(0)$, must be the probability of that one is the only seller in the preferred set, $(\frac{p}{t}) \cdot (1 - \frac{p}{t})^{n-1}$. Hence, the profit of a seller j that bids 0 must be $(\frac{p}{t}) \cdot (1 - \frac{p}{t})^{n-1}(V - a(0))$. Another seller k cannot achieve higher profit since a seller j bidding 0 can simply bid at the top of k's support and achieve at least k's expected profits (it can be strictly higher if $F_j(z) < 1$ where z is the highest point in k's support.) Another seller k cannot have lower profits since k can simply bid 0 and receive profits equivalent to that of seller j. Hence, all sellers must have profits equal to $(\frac{p}{t}) \cdot (1 - \frac{p}{t})^{n-1}(V - a(0))$.

If, $p/t = 0$ or 1, the profit would be zero as in all the possible equilibria in a standard all-pay auction with incomplete information (see Baye, Kovenock, and de Vries, 1996, and Kaplan, Luski, Wettstein, 2003). This is consistent with our formula for expected profits. ■

Proof of Proposition 1.

First, we will show that any equilibrium must be symmetric. Assume that in equilibrium there is an j, k and z where z is in the support of j and k, but $F_j(z) \neq F_k(z)$. Since z is in the support of j and k, we must have $W_j(z)(V - a(z)) - z = W_k(z)(V - a(z)) - z = (\frac{p}{t}) \cdot (1 - \frac{p}{t})^{n-1}(V - a(0))$ which implies that $W_j(z) = W_k(z)$. However, $W_j(z) = F_k \Pi_{i \neq j,k} F_i$ and $W_k(z) = F_j \Pi_{i \neq j,k} F_i$ this implies we must have $F_j(z) = F_k(z)$. This leaves the only possibility if sellers j and k do not use the same strategy then supports of F_j and F_k are disjoint. Now notice that in equilibrium there cannot be any gaps in ΠF_i (since there are no atoms in equilibrium and a seller at the top of a gap would have incentive to lower his bid). Thus, if there are two points z_j and z_k where $z_j < z_k$ and z_j is in the support of F_j and z_k is in the support of F_k, then $F_j(z_j) < F_k(z_k)$. It then follows that there cannot be a gap in an individual F_i's support. This implies that the supports of all sellers coincide and hence so do all the F_i's. We denote this common CDF as F.

All the points in the support must yield the same expected profit. This profit must equal the gains from winning $(V - a(x))$ times the probability of winning minus the effort x. The probability of winning is the chance that all sellers are set T/P and put forth lower effort,

$(1-\frac{p}{t})^n F(x)^{n-1}$, plus the chance that the particular seller is in P and all the other sellers (if any) that are in P put forth lower effort. This latter expression is slightly more complicated and equal to

$$\frac{p}{t} \cdot \sum_{m=0}^{n-1} \left(\begin{array}{c} n-1 \\ m \end{array} \right) (\frac{p}{t})^m (1-\frac{p}{t})^{n-1-m} F(x)^m.$$

Combining yields equation (1) which for each x has a unique solution for $F(x)$. The second half of the proposition has the problem reduce to that of one with bid-dependent rewards, an environment studied by Kaplan, Luski and Wettstein (2003). Here, there is a possibility of an atom at zero. However, similar to the above, there is a unique equilibrium among active participants (a seller i is active if there exists an $x_i > 0$ where $F_i(x) < 1$). $\blacksquare$

Proof of Proposition 2.

(i) Remember that the expected seller profit without information release (Lemma 1) is $\pi(n, \frac{p}{t})$. The ex-ante expected profit for a particular seller i in the case of information release is $\frac{1}{t} \sum_{t_i \in T} \sum_{s \in S} r(s) \pi^i(t_i, s)$ where $\pi^i(t_i, s)$ is the expected profit for seller i of style t_i after the information s is released and $r(s)$ as the probability s would be sent. This probability depends upon the function g used and equals $r(s) = \sum\limits_{P \in \mathbb{P}} \frac{g_s(P)}{\#\mathbb{P}}$ where $g_s(P)$ represents the probability s is sent when the true preferences are P.

After the information is released, for the same reasons as in Lemma 1, there can't be atoms in the distribution. For this reason, the effort of zero must be in the support (otherwise, if one will have the lowest effort in any case, it might as well be zero). Since it is a mixed strategy, the expected profit must be equal for all points in the support including zero. Hence, we can look at the expected profit for an effort of zero. This is simply $V - a(0)$ times the probability of being the only preferred seller. The probability equals $\mu_i(t_i, s)(1-\frac{p}{t})^{n-1}$ where $\mu_i(t_i, s)$ is the probability of a seller of style t_i is in P when signal s is sent. Denote $\mathbb{P}(t_i) \equiv \{P \in \mathbb{P} : t_i \in P\}$. We can then write $\mu_i(t_i, s) = \sum\limits_{P \in \mathbb{P}(t_i)} \frac{g_s(P)}{\#\mathbb{P} \cdot r(s)}$. Hence, $\pi^i(t_i, s) = \mu_i(t_i, s)(1-\frac{p}{t})^{n-1} (V - a(0))$.

However, $\frac{1}{t}\sum_{t_i\in T}\sum_{s\in S} r(s)\pi^i(t_i,s) = \frac{1}{t}\sum_{t_i\in T}\sum_{s\in S} r(s)\left(\sum_{P\in\mathbb{P}(t_i)} \frac{g_s(P)}{\#\mathbb{P}\cdot r(s)}\right)(1-\frac{p}{t})^{n-1}\left(V-a(0)\right)$.
We now can make a further simplification:

$$\frac{1}{t}\sum_{t_i\in T}\sum_{s\in S} r(s)\left(\sum_{P\in\mathbb{P}(t_i)} \frac{g_s(P)}{\#\mathbb{P}\cdot r(s)}\right) = \frac{1}{t}\sum_{t_i\in T}\sum_{s\in S}\left(\sum_{P\in\mathbb{P}(t_i)} \frac{g_s(P)}{\#\mathbb{P}}\right) =$$

$$\frac{1}{t}\sum_{t_i\in T}\left(\sum_{P\in\mathbb{P}(t_i)} \frac{\sum_{s\in S} g_s(P)}{\#\mathbb{P}}\right) = \frac{1}{t}\sum_{t_i\in T}\left(\sum_{P\in\mathbb{P}(t_i)} \frac{1}{\#\mathbb{P}}\right) = \frac{1}{t}\sum_{t_i\in T}\left(\frac{\#\mathbb{P}(t_i)}{\#\mathbb{P}}\right).$$

Now note that $\#\mathbb{P} = \binom{t}{p}$and $\#\mathbb{P}(t_i) = \binom{t-1}{p-1}$. Thus, $\frac{1}{t}\sum_{t_i\in T}\left(\frac{\#\mathbb{P}(t_i)}{\#\mathbb{P}}\right) = \binom{t-1}{p-1}/\binom{t}{p} = \frac{p}{t}$.
Hence, we have $\frac{1}{t}\sum_{t_i\in T}\sum_{s\in S} r(s)\pi^i(t_i,s) = (\frac{p}{t})\cdot(1-\frac{p}{t})^{n-1}\left(V-a(0)\right) = \pi(n,\frac{p}{t})$.

Since the sellers cannot switch styles, then the probability that the buyer will get a proposal in the preferred style will not change. We show in Example 3 that the effect on the buyer's surplus can go either direction.

(ii) To show that the information can be damaging when sellers can switch their style, let us look at an example. Let us say that there are two sellers, $p = 1$ and $t = 2$. Profit for each seller is $\pi(2,\frac{1}{2}) = \frac{1}{4}\left(V-a(0)\right)$. Now let us say the sellers are full flexible in switching style. If the buyer communicates his preferences by mentioning exactly which style is preferred, then each seller would switch to the preferred style and profit will equal zero (which is $\pi(2,1)$). Hence, we see that profit can go down by the release of information.

Now we also show that the sellers' profits can go up by way of example. Let us say that there are two sellers, $p = 1$ and $t = 4$. Without communication, the sellers' profits would be $\pi(2,\frac{1}{4})$. For an example, let us return to that of a university building with two possible designs for offices: around an atrium or secluded. The building style can also be modern or classic. This makes a possible four types. There are two architecture firms competing for the design. They can't switch their style of architecture easily, but it is not difficult to change the layout. If the university announces it's preference for office layout, then both firms would switch to that style. In both cases of preference, then the profit would be $\pi(2,\frac{1}{2})$, which is the highest profit. Note that announcing also building style will have no further effect as in part (i).

Since the sellers have the ability to switch styles, communicating information about preferences to them only increases the probability that there will be a proposal in set P. This improves the buyer's surplus. ■

Proof of Proposition 3.

(i) This can be shown in a similar manner to that in the proof in Proposition 2 (i). The key is that now the information release is about the sellers' types and not the buyer's preferences. Since information about types is fully revealed and $T_i = \{t_i\}$ for all i, the set of possible states sent is $S = T^n$. Denote s as the actual information announced and s_i as the type of seller i. The overall profit is $\sum_{s \in S} r(s)\pi^i(s)$ and the profit for each case of information release is $\pi^i(s) = \mu_i(s)\,(V - a(0))$ where $\mu_i(s)$ is the probability of seller i being unique in the preferred set when the state is s. The probability of each state occurring $r(s)$ is simply $1/\#S = 1/(T \cdot n)$. The probability of being unique in the preferred set $\mu_i(s) = 0$ if there exists a $j \neq i$, where $t_i = t_j$. The odds of this occurring is $1 - (\frac{t-1}{t})^{n-1}$.If this is not the case and for all $j \neq i$, we have $t_i \neq t_j$, then $E[\mu_i(s)|t_i \neq t_j] = \frac{p}{t} \cdot (1 - \frac{p-1}{t-1})^{n-1}$. The odds of this occurring is $(\frac{t-1}{t})^{n-1}$. Overall, we have $\sum_{s \in S} r(s)\pi^i(s) = (\frac{t-1}{t})^{n-1} \cdot \frac{p}{t} \cdot (1 - \frac{p-1}{t-1})^{n-1}\,(V - a(0)) = \frac{p}{t} \cdot (1 - \frac{p}{t})^{n-1}\,(V - a(0)) = \pi(n, \frac{p}{t})$.

(ii) Let us first look an example where seller information helps the buyer's surplus. When $a(x) = 0$, $n = 2$, $p = 1$ and $T_i = \{t_i\}$. Without information, sellers choose effort according to $V\left(\frac{1}{4} + \frac{1}{2}F(x)\right) - x = \frac{1}{4}V \implies F(x) = 2x/V$. There is a 1/2 chance that the sellers have the same style. When this is the case, we look at the expected maximum of $V/3$. When they have different styles, we look at the average of $V/4$. Overall, the expected surplus is $(7/24)V$.

In the case when sellers' types become public knowledge, when the sellers have the same style, they use G according to $V \cdot G(x) - x = 0$. This implies $G = x/V$, which is uniform on $[0, V]$. The expected maximum effort is then 2/3. When the sellers have different styles they choose zero effort since either they are unique in the preferred set or the other seller is in the preferred set. Since each possibility occurs half the time, overall the expected effort is 1/3. This is higher than when there is no information.

For an example where the buyer surplus is higher without seller information, take the previous example, but change the possible seller types. Now the possible types are $\{1, \{1\}\}$, $\{2, \{2\}\}$, $\{1, \{1, 2\}\}$, $\{2, \{1, 2\}\}$ with an equal chance of each. Whenever, $T_1 = T_2 = \{1, 2\}$, it is an equilibrium to randomly choose one's type. This has the same payoff as the equilibrium without information being passed and sellers can't switch. It occurs 1/4 of the time. For all the cases when $\#T_1 = \#T_2 = 1$, we have the same expected payoff as the case when information is passed and sellers cannot switch. When $\#T_1 \neq \#T_2$, the equilibrium is for sellers to have different styles. This generates 0 effort. The expected effort is $\frac{1}{4} \cdot \frac{7}{24} + \frac{1}{4} \cdot \frac{1}{3} = \frac{5}{32}$. This happens 1/2 the time. In this case, without switching the there is a seller with a preferred style 3/4 of the time. With switching, there is a preferred style all the time. Thus, with information, there is a surplus increase of $\rho/8$ from a preferred style of being more likely. Not sending information yields higher buyer surplus if $\frac{7}{24} > \frac{5}{32} + \frac{\rho}{8}$ or $\rho < \frac{13}{12}$. Since we only require ρ to be greater than 1, this is possible.

(iii) Here the equilibrium requires sellers choosing both a style in their set and an effort. When choosing the style, sellers maximize profit if they are able to differentiate themselves from one another. This increases the chance that they will be the sole seller in the preferred set. (There is still an equal chance for each style to be preferred by the buyer.) If $T_1 \neq T_2$, then the equilibrium choice of style will be different even if the original default styles were the same ($t_1 = t_2$). This is because seller i can chose a $\widetilde{t}_i \in T_i/T_{-i}$ where it is certain that the other seller will choose. By doing so, seller i maximizes the chances that he would be alone in the preferred set. It is less clear what will happen if $T_1 = T_2$. To illustrate this assume that $T_1 = T_2 = \{1, 2\}$, $t_1 = 1$ and $t_2 = 2$. This is a standard coordination game. While initially they are on different styles and it is an equilibrium to stay with the defaults, there is another equilibrium where they choose between 1 and 2 with equal probability. In such a game, this mixing yields the lowest equilibrium payoff. From this we see that the lowest possible equilibrium payoff for the sellers happens when they choose with equal probability each style in their set whenever $T_1 = T_2$.

How does this compare to profit in the default equilibrium? Notice that profits in the default equilibrium are the same as when all sellers choose with equal chance among all the possible styles in their set– there is still the same chance of another seller having the same style. Let us now use this as a baseline and look at the case when the sellers' types are made public. Whenever $T_1 = T_2$, the lowest possible new payoffs are the same as our baseline. Whenever, $T_1 \neq T_2$ the payoffs strictly increase compared to the baseline. Hence, the addition of such information is beneficial to the sellers. ■

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