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SELF-CORRECTING MECHANISMS IN PUBLIC PROCUREMENT: WHY AWARD AND CONTRACT SHOULD BE SEPARATED

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Abstract

In public procurement a temporal separation of award and actual contracting can frequently be observed. In this paper we give an explanation for this institutional setting. For incomplete procurement contracts we show that such a separation may increase efficiency. We show that efficiency can be increased by post-award, pre-contract negotiations between the award-winning seller and one of the 'losing' sellers. Surprisingly, the efficiency gains can be higher if the award is given to a seller with a lower reputation for quality instead of to a seller with higher reputation. Under certain conditions post-award, pre-contract rent-seeking activities also increase efficiency. This is always the case if the procurement agency is corrupt, but may also occur in the case of lobbying.

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1 Introduction

Public procurement amounts to 10-15 percent of the GDP in the US and in Western European countries. The overall efficiency of an economy, therefore, is decisively influenced by the efficiency of the procurement procedure. This paper explores the consequences of a temporal separation of award and actual contracting in public procurement. In such a setting the *award* is the government's official statement of the intention to buy a particular seller's project. The *contract* on this project is signed later, maybe with another seller. The separation of award and contract gives higher-quality sellers a better chance to become contractor because disappointed offerors can sue for the contract, whereas according to European law they can only sue for monetary compensation if award and contract are unified. In countries like France, Belgium and Italy award and actual contract have been separated for a long time. Other countries, like Germany, will have to introduce such a separation because in 1999 the European Court of Justice explicitly ruled that a temporal separation of award and contract is required.[1] The EU favors such a separation because it makes it more difficult for a procurement agency to discriminate foreign offerors, which would contradict the common-market philosophy. In the US federal procurement, there is no explicit distinction between award and actual contracting. However, in the Federal Acquisition Regulations (FAR) there is a provision which may result in a timing of potential sellers' legal protection which is equivalent to a separation of award and actual contracting. "A particular subject of interest concerns whether and how a disappointed bidder or a pleased but challenged awardee wage their struggle if the protest of the award halts proceeding with the contract." (Tiefer and Shook, 1999, p. 496)[2] Therefore, although award and actual contracting are unified in the FAR, a post-award (= post-contract) protest may lead to a termination of the initial contract, thus effectively separating award and contract.

Why can a separation of award and actual contracting improve efficiency? Consider a situation where a government agency wants to procure a project from one of two potential private sellers. The value of the project is q if the agency signs the contract with the right seller and zero otherwise. Unfortunately, for one reason or another, the agency chooses the wrong contractor with a probability of $(1 - x)$. Thus, the expected value of the project is xq. The agency has an interest to

[1]The judgment of the European Court of Justice, October 28, 1999, is an interpretation of the Council Directive 89/665/EEC.

[2]For details see FAR, §14.408-8 (sealed-bid auction), §15.507 (contracting by negotiation) and §33.104 (c)(4)(5) (protests after award).

improve the probability that the right seller is chosen, for instance from x to $z > x$. This can be attained by a separation of award and contract because this enables the potential sellers to negotiate after one of them has got the award. As will be shown in this paper, these negotiations increase the probability that the right seller signs the contract. Influencing the sellers' negotiations may require quite unexpected strategies of the agency: it is the most challenging result of this paper that it might even be optimal if the agency gives the award to the seller which looks inferior. It is possible that such a strategy should be chosen because it makes it more probable that in their negotiations the sellers choose the right one and this may overcompensate the initial disadvantage of giving the award to the inferior looking seller. If the agency dispenses with this strategy, it wastes an important channel to influence the outcome of negotiations between the sellers.

Recall the general insight of Coase (1960) that the allocation of property rights is irrelevant from an efficiency point of view as long as transaction costs are negligible and contracts are perfect. Otherwise, if the contractual arrangements do not allow the exclusion of the probability of wrong decisions, the distribution of property rights can have an influence on efficiency. In this paper, giving the award to one of the sellers endows him with a specific right that shapes the sellers' negotiations. Therefore, a separation of award and contract can be explained as a rational institutional arrangement in environments where decisions are necessarily imperfect. In these cases, contractual arrangements that allow for a certain flexibility will do better than inflexible contractual arrangements. In this paper, contracts with built-in flexibility will be called "self-correcting mechanisms." The separation of award and contract in public procurement is a prominent example of such a mechanism. However, the main idea of the paper carries over to all kinds of contractual arrangements that suffer from imperfections.

Flexibility becomes important if it is impossible to avoid mistakes in the selection of a trading partner. This intuition, straightforward as it is, might be objected to on purely theoretical grounds: despite contractual incompleteness the procurement agency could use a direct mechanism, that is, an auction to select the "right" trading partner. In such an ex-ante auction a better type would be able to make a higher offer. Consequently, flexibility could not improve upon this solution. However, an auction will only operate successfully if the quality of the project can precisely be specified ex ante.[3] In contrast, our paper applies to projects where quality can only poorly be specified ex ante.

[3] Compare Teece (1988).

The poor specifiability of quality is the reason why in practice public procurement only rarely has the structure of an auction, and if it has, in general it would not be an optimal mechanism. In the US, for example, it is not the sealed-bid auction, but competitive negotiation which "is by far the most common method by which the government purchases products and services with a value in excess of the simplified acquisition threshold of \$ 100,000." (Tiefer and Shook, 1999, p. 77) Real-world procurement contracts suffer from imperfections most of the time and it is for this reason that flexibility becomes important. In this paper we want to contribute to a better understanding of these practical contracts. It is not the purpose of this paper to derive conditions which show how far auctions can approach an efficient solution of the allocation problem in the case of poorly specifiable quality.[4]

We will analyze the following situation. Two sellers compete for a public project that one of the sellers will eventually carry out. The contract should be signed with the highest-quality seller, as corresponds to a setting of negotiated procurement (whereas procurement by sealed-bid auction always is based on price). When the award is given, each seller knows the quality of his project but not the quality of the other seller's project, whereas the procurement agency does not observe either quality. However, the agency and the other seller observe a signal which refers to the reputation of the seller and which is positively correlated with the quality that is achieved if the project is carried out by this very seller.

When the award is given, each seller is better informed about his quality than the procurement agency. Thus, there are potential gains from *negotiations* between both sellers that cannot be utilized if the agency immediately signs the contract with the award-winning seller. However, these potential gains can be utilized whenever the result of sellers' post-award pre-contract negotiations depends on who got the award. Assume that each seller can credibly commit to a strategy in a game which is to be played before an authority entitled to revoke the award – this could be an arbitrator, the procurement agency itself, or a court. The sellers' strategies can serve as signals for the revocation authority which may induce the authority to rescind the award. – One might argue that a separation of award and contract is not necessary to bring about efficiency increases by negotiations between potential sellers. Alternatively, the sellers could negotiate *before* award and contract are simultaneously enacted. However, first, this is not always possible: the potential rival sellers may not know each other before the award, which trivially makes pre-award negotiations impossi-

[4]For a more detailed discussion of the admissibility of such an applied approach see, for example, Besley and Coate (1998).

ble. Second, as we shall see below,[5] the separation of award and contract gives the procurement agency additional strategic flexibility which cannot be replicated by pre-award negotiations between the sellers.

Whereas pre-award negotiations typically are the sort of collusive behavior which is unwanted in regulatory processes, the sellers' post-award negotiations could be seen as part of an arbitration process. The sellers meet, possibly in the presence of an arbitrator or a representative of the procurement agency and enter into negotiations. As result of the negotiations the arbitrator or the agency may receive a signal according to which the award should be revoked because a switch to another seller will increase efficiency. Note, however, that the efficiency-improving consequences of post-award negotiations do also hold if the negotiations are "pure collusion." In this case our paper provides the message that pure collusion can be good if the institutional environment has appropriately been shaped, as is the case in our paper. Therefore, readers who dislike the idea that sellers negotiate which strategies they will apply before a court, should recognize that in our paper the environment of these negotations has been set so as to guarantee that the collusion is efficiency-improving.

An alternative institutional setting is *rent seeking*. During the time between award and contract, any seller has an incentive to engage in rent-seeking activities in order to influence the probability that he gets the contract. Rent-seeking outlays can be used as information about the true value of the project because – as will be shown in this paper – high-quality sellers will engage more heavily in rent-seeking activities than low-quality sellers. Thus, as in the case of negotiations between the sellers, the probability of contracting with the wrong seller can be reduced. Whether the improvement in the agency's informational status implies an efficiency gain or not, depends on the specification of rent-seeking activities: if the activities are zero-sum in nature (corruption), efficiency increases, whereas in the case of negative-sum rent seeking (lobbying), the positive information effect has to be compared with the negative effect of wasted lobbying outlays.

The paper is organized as follows: In section 2 we present the model. In section 3 we analyze the benchmark case of unseparated award and contract. In section 4 we extend the game by separating award and contracting and look for negotiations between the sellers. In section 5 we analyze the case of rent seeking. Section 6 concludes.

[5] See subsection 4.2 below.

2 The model

Let us consider a situation where a government procurement agency purchases an indivisible project. Two sellers, indexed $k = i, j$, offer their services, but only one of them will become the contractor. The value of the project (benefit minus costs) is $q_k \in [\underline{q}, \overline{q}]$ if the project is carried out by seller k. Abbreviating we shall denote q_k as 'quality' of the project and of seller k, respectively. At the contracting stage, the procurement agency cannot observe the qualities offered by the sellers. However, it observes signals $e_k > 0$ which can be thought of as exogenously given reputations of the sellers.[6] Therefore, the agency has to base its decision on the signals $\{e_i, e_j\}$.

Any signal is positively correlated with quality. Let $f_k(q) := f(q \mid e_k)$ be the probability that a project of quality q is realized if the signal is e_k and $F_k(q) := F(q \mid e_k) = \int_{\underline{q}}^{q} f_k(r)dr$ be the associated distribution function. Then for $\widetilde{e}_k \geq \hat{e}_k$ we assume

$$F(q \mid \widetilde{e}_k) \leq F(q \mid \hat{e}_k). \tag{1}$$

This assumption implies first-order stochastic dominance: higher quality is more probable, the higher a seller's reputation signal.

We follow the incomplete-contract methodology initiated by Grossman and Hart (1986) and Hart and Moore (1988) and applied to government contracting by Bös and Lülfesmann (1996, 1997). Accordingly, we assume that the reputation signals are not verifiable before a court or an arbitrator (although they are common knowledge): reputation could only be described by many characteristics, some of which cannot actually be measured but are subjective in nature. The quality is non-verifiable private information when the agency and one of the sellers sign the procurement contract. We assume that at this moment there are so many characteristics which can be combined into various qualities that it is too costly (or impossible) to make contractual provisions for every single quality realization.[7] However, ex post, when the project has actually been carried out, quality becomes known to everyone and becomes verifiable before a court.

We assume that the procurement agency wants to buy quality, it is not interested in a cheap price if this implies lower quality. Unfortunately, however, it is impossible to condition an ex-ante price on unverifiable private information of a seller. Therefore, the only type of procurement contract that can be signed ex-ante specifies the seller

[6] In an alternative setting, one could deal with signals which can be interpreted as plans or models that specify the details of the project. Then the signals would be endogenous and the costs of signaling would explicitly have to be considered.

[7] On this point see Hart and Moore (1999).

who will carry out the project and is contingent on the events "some project is realized" and "no project is realized." Although this contract does not stipulate an ex-ante price, all parties know how the ex-post payment to the private contractor will be determined. The compensation of the seller who carries out the project will be negotiated ex-post, after the realization of the project, when the quality of the project is known and verifiable. In this paper we are not interested in the exact process of this negotiation. We therefore follow the literature[8] and assume that the ex-post negotiated price π for the seller is some fraction $\alpha \in [0, 1]$ of the value of the project q. The remaining fraction $\beta(= 1 - \alpha)$ goes to the procurement agency. In the following we will call βq the *public value* of the project. Anticipating the ex-post negotiations, at the moment of contracting each seller knows exactly what he will get if he becomes contractor (since he knows his own quality). The agency only knows the expected payment it will face if signing the contract with a particular seller.

Figure 1 presents the sequences of events which are alternatively treated in the various sections of this paper. We deal with the following settings:

(a) As a benchmark we consider a setting where award and contract are not separated, but unified. After the qualities and the reputation signals are given at stage 0, the potential sellers may negotiate who makes an explicit offer to the agency (date 1/2). Recall that the qualities are private information. Therefore, negotiations are not meaningful until after the reputation signals have been announced. Afterward, at stage 1, the procurement agency simultaneously chooses one seller and signs the contract with this very seller. We denote the agency's strategy as s_G, where $s_G \in \{i, j\}$ specifies the winning seller.

(b) In the alternative settings, award and contract are separated. In these cases, at stage 1 the procurement agency gives the award to one of the sellers. Strategy $s_G \in \{i, j\}$ specifies the award-winning seller (in the following called the winner, whereas his counterpart will be called the loser). In contrast to the benchmark case, the contract is signed at a later stage. This raises the question of how far the award is binding for the agency. We assume that the award binds the agency unless it is revoked, because a "recovation uthority" (RA) receives a signal that the award was given to the inferior-quality seller. It depends on the procurement law whether the RA is an arbitrator, the procurement agency itself, or a court.

After the award has been announced, but before the contract is signed, the loser

[8]See Aghion and Tirole (1994), Che and Hausch (1999), Edlin and Reichelstein (1996) and Grossman and Hart (1986).

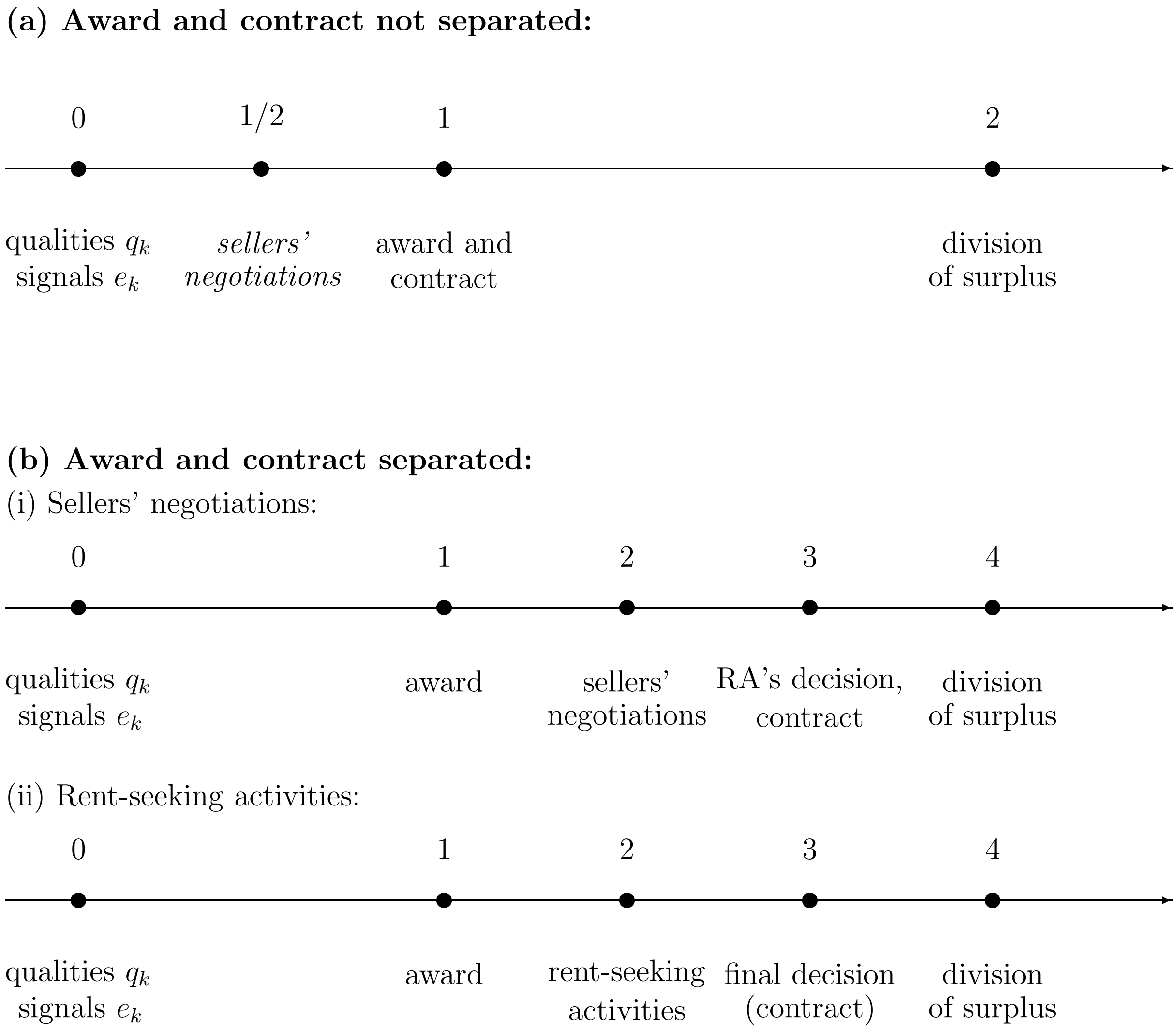

Figure 1: The timing of the games.

will try to reverse the agency's decision. To achieve this he can either enter into negotiations with the winner, which may lead to a game played before the RA, or he can use political channels to influence the procurement agency by rent-seeking activities (which will of course give rise to counteractions of the winner). For conceptual clarity we assume that "negotiations" and "rent seeking" are two separate settings, although in practice they can of course occur simultaneously.

(i) Negotiations: the separation of award and contract gives free scope for negotiations between the sellers. At stage 2 the loser can ask the winner to "sell" his right to sign the contract. As a consequence of these negotiations, at stage 3 the loser can go to the RA to claim the contract. The winner can either confirm the loser's claim before the RA or oppose it. The RA observes the strategies of the sellers and utilizes them as signals. If the RA confirms the award, the winner signs the contract. If the RA revokes the award, the loser signs the contract.

(ii) Rent seeking: alternatively, the separation of award and contract may give free scope for rent-seeking activities of the sellers at date 2. If the loser's lobbying activities give a signal that his quality is higher than the winner's, then the agency will revoke the award at date 3. It should be mentioned that the same may hold true if the agency is corrupt. (Revocation by a court or an arbitrator is of no relevance in the case of rent seeking.)

The final stage of the game is identical for all of the various settings of the paper: at stage 4 the project is carried out by the contract-signing seller, for example i, its quality is observed by the procurement agency and the price $\pi = \alpha q_i$ is negotiated and paid to i.

The *objective functions* of the players are as follows: both sellers are risk neutral and maximize profits. Procurement agency, arbitrator and court are also risk neutral. They maximize the public value of the project. Detailed presentations of these objective functions will be presented in the following sections.

3 A Benchmark

As a benchmark we analyze the situation which is treated in the standard literature on procurement: award and contract are not separated, and there are no pre-award negotiations between the potential sellers. We shall show that the resulting allocation is inefficient and, therefore, one has to look for remedies of the imperfection as will be done in the sections to follow.

The procurement agency anticipates that an ex-post public value of βq_k will be accomplished at stage 4 if seller k had been chosen as contractor. Therefore, at stage 1 the agency gives the award according to the following strategy:

$$s_G = i \quad \Leftrightarrow \quad \beta\mu_i \geq \beta\mu_j, \tag{2}$$

where $\mu_k = E[q \mid e_k], k = i, j$, is the expected value of q given signal e_k. It follows immediately that the agency will give the award to the seller with the higher signal.[9]

[9] This follows directly from first-order stochastic dominance and can easily be proved. We have $\beta\mu_k = \beta\int_{\underline{q}}^{\overline{q}} q f_k(q)dq = \beta\left(\overline{q} - \int_{\underline{q}}^{\overline{q}} F_k(q)dq\right)$. Hence, $\beta\mu_i \geq \beta\mu_j \Leftrightarrow \beta\left(\int_{\underline{q}}^{\overline{q}} (F_i(q) - F_j(q))\, dq\right) \leq 0 \Leftrightarrow e_i \geq e_j$. The last equivalence follows from our assumption of first-order stochastic dominance.

We obtain the following result:

Result 1: If award and contract are simultaneously enacted, the optimal decision rule of the procurement agency is

$$s_G = i \quad \Leftrightarrow \quad e_i \geq e_j. \qquad (DR)$$

The expected payoff of the agency is $\beta\mu_i$.

Because of the imperfection of the quality signal e_i, it cannot be expected that the decision rule DR is perfect. In fact, the probability of making a wrong decision is

$$prob\,(q_j > q_i \mid e_i \geq e_j) = \int_{\underline{q}}^{\overline{q}} \int_{\underline{q}}^{q_j} f_i(q)dq f_j(q_j)dq_j = \int_{\underline{q}}^{\overline{q}} F_i(q_j)f_j(q_j)dq_j. \tag{3}$$

Let us now ask whether DR is the optimal decision rule given the contractual environment analyzed in the paper: is the deviation from the first-best allocation present in decision rule DR due to the necessary restrictions imposed by the incomplete-contract setting or due to an unnecessarily imperfect contract design? The latter is correct: the decision rule DR exhibits an idiosyncratic imperfection. A first hint that this claim is correct is given by the observation that information is wasted with this decision rule. Assume for a moment that the loser (w.l.o.g. called j) was to act in the pure interest of the procurement agency. At the awarding/contracting stage he is better informed than the agency because he knows $\{e_i, e_j, q_j\}$, whereas the agency only knows $\{e_i, e_j\}$. If he would decide according to the objective function of the agency, his decision rule would be:

$$s_j^G = i \quad \Leftrightarrow \quad \beta\mu_i \geq \beta q_j \quad \Leftrightarrow \quad \overline{q} - q_j \geq \int_{\underline{q}}^{\overline{q}} F_i(q)dq. \tag{4}$$

Result 2: The decision rule DR makes no use of the information held by the sellers. If the informational advantage of the sellers could be used in a decision rule, the expected payoff of the procurement agency could be increased. If $e_i \geq e_j$, it would increase to $\max\{\beta\mu_i, \beta q_j\} \geq \beta\mu_i$ if the loser decided in the pure interest of the agency.

Therefore, if we can find a way to use the information wasted with DR, this could lead to less imperfect decision rules. In the next section, we will look for mechanisms that make use of this information.

4 Negotiations between sellers

4.1 Award and contract separated

Let us begin with the treatment of *stage 3.* Without limitation of generality we assume that seller j is the loser. The separation of award and contract allows him either to do nothing ($s_j = 0$) or prosecute the revocation of the agency's initial decision ($s_j = 1$). The winner can either confirm the loser's position ($s_i = 1$) or oppose it ($s_i = 0$). The decision of the revocation authority (RA) is based on the sellers' strategies $\{s_i, s_j\}$. The RA can either revoke ($s_{RA} = 1$) or confirm ($s_{RA} = 0$) the award. In doing so it tries to maximize the public value of the project βq.

Recall that the reputation signals $\{e_i, e_j\}$ are not verifiable before a court or an arbitrator. Hence, these RAs cannot revoke an award because the procurement agency chose the seller with the inferior reputation signal. If the procurement agency itself is RA, it knows the reputation signals. However, it has already used this information when deciding on the award and it will revoke its own decision only if it gets new information. Hence, despite the difference in the informational positions of court, arbitrator and procurement agency, their revocation strategies are the same.

We claim that the following revocation strategy is optimal whatever the sellers do at stage 2:

$$\begin{aligned} s_i s_j = 1 \quad &\Rightarrow \quad s_{RA} = 1, \\ s_i s_j = 0 \quad &\Rightarrow \quad s_{RA} = 0. \end{aligned} \tag{5}$$

As will be shown shortly, this strategy is part of a Nash-equilibrium of the game. Note that for notational convenience the RA's strategy has been defined so as to include fictitious decisions of the RA when it is not involved because the loser is inactive ($s_j = 0$).

Given the strategy of the RA, the sellers can negotiate their strategies before going to the RA. This is done at *stage* 2. At this stage the qualities are still private information. Hence, the only possible agreement of the sellers specifies a price p paid by the loser and a pair of strategies $\{s_i, s_j\}$. After both parties have negotiated such an agreement, the loser approaches the RA. In order to model the negotiations in the simplest possible way we assume that the loser makes a take-it-or-leave-it offer to the winner. This assumption has no influence on the qualitative results of the paper.[10]

[10]Different negotiation procedures would affect the distribution of the surplus but not the al-

We distinguish between two cases: in case (a) no seller can credibly commit to a strategy before the RA; in case (b) the sellers can credibly commit. We apply backward induction to solve these two cases.

(a): No credible commitment to a strategy before the RA

Stage 2: If the sellers cannot commit at stage 2, it is a (weakly) dominant strategy for the winner to always oppose ($s_i = 0$). He knows that the loser is unable to offer him a suable amount of money which could compensate him for giving up the right to carry out the project. Hence, he is always better off if he gets the contract ($\alpha q_i > 0$). And he can guarantee himself the contract by always opposing. The strategy of the loser does not matter. Regardless of whether he goes to the RA or not, he never gets the contract. Since the winner can always guarantee himself the contract, even if $q_i < q_j$, no information about the true values of q_i and q_j is revealed by the choice of strategies regardless of whether the loser claims the contract or not.

Stage 1: Anticipating the strategies of the sellers, the best the procurement agency can do is to stick to decision rule DR.

Note that the strategies chosen at stages 1 and 2 rationalize the above claim for an optimal RA strategy: the best the RA can do, given the strategies of the agency and of the sellers, is to confirm the award ($s_{RA} = 0$). This is the best possible solution because the RA cannot extract any new information from the sellers' strategies.

> **Result 3:** If no seller can credibly commit to an RA strategy, the separation of award and contract cannot improve upon the decision rule DR.

(b): Credible commitment to a strategy before the RA

Stage 2: If the sellers can commit at stage 2, for example by the deposition of a pledge at a third, neutral party, we obtain the following optimal strategies. Since the loser cannot observe the winner's quality, his take-it-or-leave-it offer of p is based on the following optimization approach:

$$\max_p prob[\alpha q_i \leq p](\alpha q_j - p), \tag{6}$$

locative efficiency if either some final negotiation stage and a final proposer are ex-ante specified or if the surplus is divided according to some cooperative sharing rule. If negotiations are modelled as in Hart and Moore (1988), some loss of efficiency is possible. This, however, would only have a quantitative effect, but no qualitative effect, on our results. – Note that all qualitative results of the paper are also valid if the winner makes a take-it-or-leave-it offer to the loser.

where $(\alpha q_j - p)$ is what the loser gets if he succeeds and $prob[\alpha q_i \leq p]$ is the probability that the winner accepts the loser's offer. We know that $prob[\alpha q_i \leq p] = prob[q_i \leq p/\alpha] = F_i(p/\alpha)$, and substitute this in (6). Then, a local maximum of the loser's optimization problem is characterized by the following first- and second-order conditions:[11]

$$(1/\alpha) f_i(p/\alpha)\,(\alpha q_j - p) - F_i(p/\alpha) = 0, \tag{7}$$

$$(1/\alpha^2) f_i'(p/\alpha)\,(\alpha q_j - p) - (2/\alpha) f_i(p/\alpha) < 0, \tag{8}$$

where $f'(\cdot)$ denotes the first derivative of f with respect to $(\cdot)$.

Any positive price offer $p(q_j) > 0$ is increasing in the loser's quality as can easily be shown by applying the implicit-function theorem:

$$\frac{dp}{dq_j} = -\frac{f_i(p/\alpha)}{SOC} \geq 0. \tag{9}$$

The term SOC in the denominator denotes the second-order condition (8) which is smaller than zero by assumption.

We will first show that negotiations are only successful if the loser has higher quality than the winner ($q_j \geq q_i$). As a first step to establish this conclusion we will prove the following lemma:

Lemma 1: The loser has no incentive to overinvest, that is, $p \leq \alpha q_j$.

Proof: Assume to the contrary that $p > \alpha q_j$. In this case, the loser makes a negative profit. This, however, contradicts the assumption that p is the maximum with the highest expected profit since the loser can always guarantee himself a zero profit by choosing $p = 0$. q.e.d.

On the other hand, the winner will only accept the loser's offer if $\alpha q_i \leq p$. Therefore, successful negotiations require that $\alpha q_i \leq p \leq \alpha q_j$, which establishes our claim:

Lemma 2: Post-award negotiations can only be successful if the award has been given to the inferior seller.

[11] Note that for the results of this paper it is not necessary to require existence or uniqueness of an interior solution. It is sufficient to know that (7) and (8) can be fulfilled for some distribution functions and that in this case the optimal price offer is implicitly defined by (7). If there are several optima, we will use the convention that the loser chooses that with the highest expected profit.

We will next check whether post-award negotiations can implement the first best, that is, negotiations are successful whenever $q_i < q_j$. This, however, requires that $p = \alpha q_j$ since otherwise there is a strictly positive probability that $q_i < q_j \wedge p < \alpha q_i$. If $p = \alpha q_j$, equation (7) simplifies to

$$-F_i(q_j) = 0, \tag{10}$$

which can only be fulfilled if the loser has the worst possible quality, $q_j = \underline{q}$. In this case, however, there are no gains from negotiations.

> **Lemma 3:** Although there might be gains from post-award negotiations, these negotiations cannot guarantee the first best.

On the other hand, for a given q_j there is a probability $prob[\alpha q_i \leq p(q_j)] = F_i(p(q_j)/\alpha)$ that negotiations are successful. Thus, from the point of view of the procurement agency, post-award negotiations improve upon the benchmark with probability

$$\int_{\underline{q}}^{\overline{q}} F_i(p(q_j)/\alpha) f_j(q) dq. \tag{11}$$

The self correction of the mechanism improves upon a situation where negotiations are excluded but the result is still imperfect.[12] Figure 2 gives a graphical illustration of the result. Assume that the loser's quality is q_j as indicated in the figure. A first-best solution requires that seller i signs the contract whenever $q_i \geq q_j$, that is, if quality i lies in the interval b of the figure. Vice versa, the first best requires that seller j signs the contract whenever $q_i < q_j$, that is, if quality i lies in the interval a. Now assume that the award has been given to seller i. As we have proved, the sellers' negotiations reverse the award if $\alpha q_i \leq p \leq \alpha q_j \Leftrightarrow q_i \leq p/\alpha \leq q_j$. Therefore, a separation of award and contract improves upon the nonseparation if q_i lies in the interval c, that is, if the loser is considerably better than the winner. If the difference between the sellers is small (interval m, for 'middle'), it is still the award-winning seller i who ends up signing the contract, despite his inferior quality. The creation of flexibility due to the separation of award and contract allows for the self-correction of imperfect decision rules, but only if the initial decision yielded 'large' losses.

It remains to be shown that the RA's revocation strategy (5) is part of a Nash-equilibrium of the game. Assume that both parties have successfully negotiated a price p and a pair of strategies $s_i = 1, s_j = 1$ (the loser goes to the RA and the winner confirms). In that case, the strategies reveal the information to the RA that

[12] This is a consequence of the impossibility theorem by Myerson and Satterthwaite (1983).

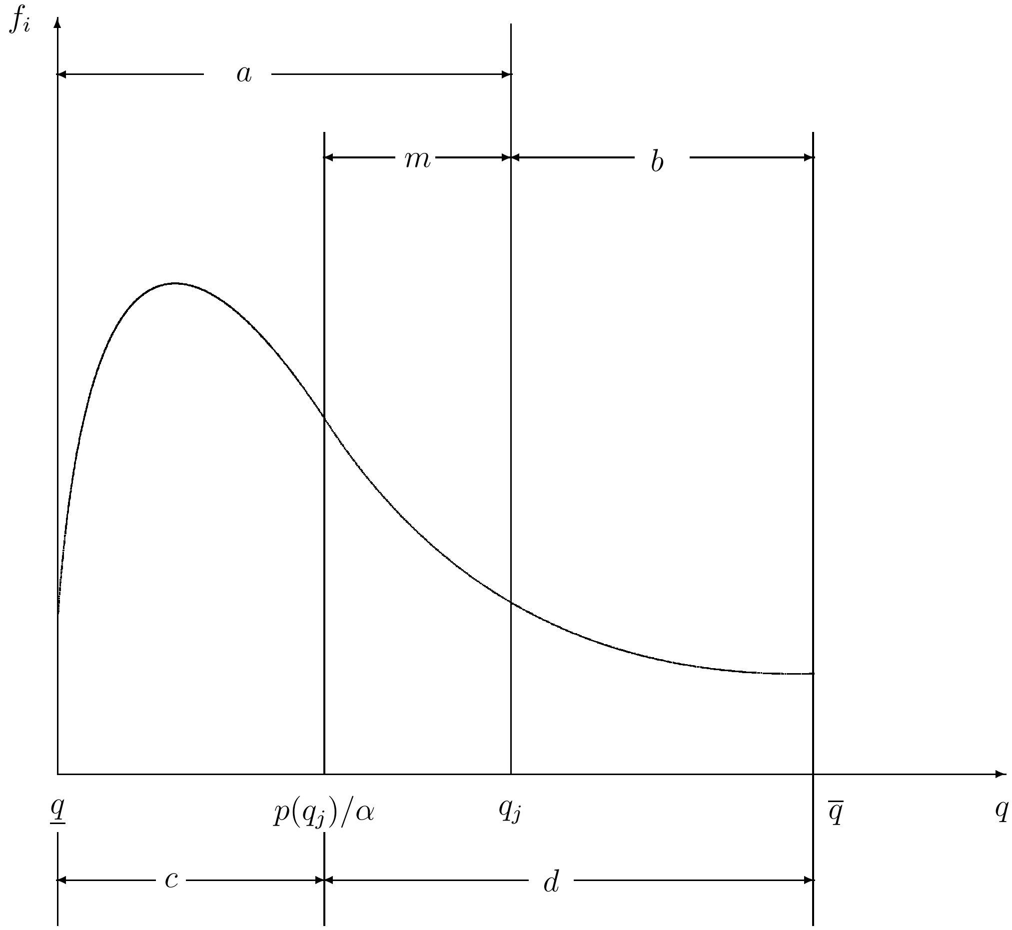

Figure 2: Efficiency-improving negotiations.

$q_j \geq q_i$. Thus, $s_{RA} = 1$ is an optimal strategy for the RA. In all other cases, the winner opposes, $s_i = 0$, and the RA confirms the award.

Stage 1: Anticipating the sellers' negotations and the RA's decision rule, the optimal strategy of the procurement agency is to give the award to the seller for whom stage 2 negotiations promise the highest ex-post payoff.

Assume that the award-winning seller has a better signal, $e_i \geq e_j$, and the procurement agency gives him the award, $s_G = i$. Then, the expected payoff of the agency is as follows: the agency always gets $\beta\mu_i$. Furthermore, in all cases where the sellers successfully negotiate, it gets $\beta(q_j - q_i) > 0$ in addition to $\beta\mu_i$. This additional payoff results from the separation of award and contract. Its expected value can be calculated as follows.

For a given q_j, the expected value of q_i given that $q_i \leq p(q_j)/\alpha$ is

$$E[q \mid q_i \leq p(q_j)/\alpha] = \int_{\underline{q}}^{\frac{p(q_j)}{\alpha}} q \frac{f_i(q)}{F_i(p(q_j)/\alpha)} dq. \tag{12}$$

Therefore, the agency's expected additional payoff for a given q_j is equal to

$$\beta F_i(p(q_j)/\alpha)\left(q_j - \int_{\underline{q}}^{\frac{p(q_j)}{\alpha}} q\frac{f_i(q)}{F_i(p(q_j)/\alpha)}dq\right). \tag{13}$$

Taking expectations over q_j gives the expected additional payoff of the agency:

$$g(i) := \beta\int_{\underline{q}}^{\overline{q}} F_i(p(q_j)/\alpha)q_j f_j(q_j)dq_j - \beta\int_{\underline{q}}^{\overline{q}}\int_{\underline{q}}^{\frac{p(q_j)}{\alpha}} qf_i(q)dqf_j(q_j)dq_j. \tag{14}$$

Summarizing, an agency that always gives the award to the seller with the higher signal ($s_G = i \Leftrightarrow e_i \geq e_j$) faces an expected payoff of

$$G(i) := \beta\mu_i + g(i). \tag{15}$$

By the same procedure we can calculate the expected payoff of an agency that always gives the award to the seller with the lower signal ($s_G = j \Leftrightarrow e_i \geq e_j$):[13]

$$G(j) := \beta\mu_j + g(j). \tag{16}$$

We are now in the position to answer the question whether the separation of award and contract improves the efficiency compared to the equilibrium of the game where award and contract are simultaneously enacted. For this purpose we define a state as *efficiency-improving* if it entails a higher sum of payoffs for all players, that is, for the procurement agency, the loser and the winner. In our particular case, we will always have a higher expected payoff for the procurement agency in equilibrium since $G(i) > \beta\mu_i$, irrespective of whether $G(i) \geq G(j)$ or $G(j) \geq G(i)$. And the sum total of the loser's and the winner's payoffs is also increased by the separation of award and contract. This separation, therefore, creates a self-correcting sequential mechanism where part of the imperfections from stage 1 is automatically internalized by the rational behavior of the agents. Summarizing, we have the following result (which follows immediately from backward induction):

> **Result 4:** There exists a subgame-perfect equilibrium of the game where award and actual contract are separated.

Let us finally turn to the explicit calculation of the equilibrium strategy of the procurement agency. The agency should choose $s_G = i$ if and only if

$$G(i) - G(j) \geq 0. \tag{17}$$

Analyzing condition (17) leads to the following result:

[13] $g(j)$ is equal to $g(i)$ after interchanging the indices i and j.

Result 5: It may be optimal for the procurement agency to give the award to the seller with the inferior signal.

This result is surprising because it demonstrates that a strategy may be optimal which at first glance seems to be inferior. The formal proof of result 5 has been relegated into appendix A.

What is the intuition for this result? Without any post-award negotiations, the procurement agency loses $\beta(\mu_i - \mu_j)$ by giving the award to j, the seller with the lower signal. However, this loss can be overcompensated by the sellers' negotiations. If these negotiations attained the first best, that is, corrected mistakes from the award stage perfectly, the optimal award strategy of the agency would be indeterminate from an efficiency point of view. However, negotiations cannot guarantee the first best, thus, in the award stage the procurement agency has to compare the relative losses which result from giving the award to either one or the other firm. Negotiations are more likely to be successful the larger the difference between the sellers' qualities. If both qualities are close, the mechanism is unable to pick the right seller. However, self correction takes place if the initial mistake is relatively large. Therefore, the procurement agency can rely on the fact that it will end up signing the contract with the 'right' seller if q_i is large and q_j small or, alternatively, if q_i is small and q_j large. Hence, the agency only has to care about the 'intermediate' ranges where the qualities are relatively close. *In this intermediate area the contingent expected value of q_j might be larger than the contingent expected value of q_i despite the fact that the opposite is true for the unconditional expected values.*

4.2 Comparison of post-award and pre-award negotiations

It is result 5 which constitutes the merit of the separation of award and contract. This can best be shown as follows. Assume that the potential sellers have known each other for some time so that it cannot be argued that the separated award is beneficial because it informs the potential sellers of their rivals. Now compare the following two settings:

(S) Separation of award and contract; post-award, pre-contract negotiations between the potential sellers are possible;

(U) Unified award/contracting stage; pre-award negotiations are possible.

If U always attained the same result as S, there would be no reason to separate award and contract.

In U, whatever the sellers negotiate, the procurement agency cannot do better than to choose the seller who signals the higher expected quality. Anticipating this decision rule, seller j will know that he will not get the award/contract if $\mu_i \geq \mu_j$. However, it is possible that this seller offers a price p that induces seller i not to apply for the contract. An inspection of the strategic incentives of the two sellers reveals that this would be the same optimization approach as treated in equation (6) for S, that is, it may be optimal for seller j to offer $p = p(q_j)$ and this offer is accepted by seller i if $\alpha q_i \leq p(q_j)$. However, the equivalence of the two optimization approaches does not prove that U always attains the same result as S. Result 5 constitutes the decisive difference. The approach S gives the procurement agency an additional strategic instrument which reveals itself in the agency's possibility to give the award to an agent with inferior signal, because the agency knows that the initial 'mistake' will be taken care of by the self-correcting property of the mechanism. This self correction and its strategic advantages do not exist in U. In other words: in U the procurement agency can only become active after the sellers' negotiations. However, in S, the agency has one more move which it makes before the sellers' negotiations. Giving the award to a seller with inferior signal is a strategic move which is based on the possibility of the procurement agency to act twice. This contractual structure cannot be replicated by pre-award negotiations between the potential sellers.[14]

Let us present this intuition in a more formal way, assuming that the negotiations are always opened by the seller who did not get the award.[15] Then, in U the pre-award negotiations are always opened by the seller j whose $\mu_j < \mu_i$. However, in S, because of the procurement agency's additional strategy instrument, the post-award negotiations may occasionally be opened by a seller who has not been given the award although his quality indicator μ exceeds that of his rival. In this case, the roles of j and i are exchanged, a price $p = p(q_i)$ is offered which is accepted by seller j if $\alpha q_j \leq p(q_i)$. This shows how the agency's additional strategy shapes the negotiations, and since we have shown that it may be welfare-improving to grant the

[14]Nothing changes if in S the potential sellers negotiate both before the award *and* after the award. The pre-award negotiations in this case would still have to consider the self-correcting mechanism, that is, the possibility that an award is given to a seller with an inferior signal.

[15]The result extends to the case where the (potential) winner makes a take-it-or-leave-it offer. It is, therefore, robust with respect to the choice of the first mover as long as the same game structure is used for both pre-award and post-award negotiations. The intuition for this result carries over to all cases where the award decision has an influence on the outcome of the negotiations between the sellers.

award to an inferior seller, S is superior to U. This can be summarized as follows:

> **Result 6:** A separation of award and contract is efficiency improving compared to a situation where award and contract are unified.

5 Rent seeking

The gap between the awarding and the contracting stage could also be used for rent-seeking activities in order to change the ex-ante decision of the procurement agency.[16] The sequencing of the game in this case has been presented in Figure 1 above. It is the same as in the previous section with one decisive exception in stage 2, where both sellers can engage in rent-seeking activities at costs $R_k, k = i, j$. These activities influence the probability $x(R_i, R_j)$ that the contract is signed with the award-winning seller (once again i). Following the literature on rent seeking, we distinguish between corruption and lobbying:[17]

- Assume first that the procurement agency gets a payment of $R_i + R_j$ if the sellers engage in activities of R_i, R_j, that is, rent seeking is zero-sum in nature. This case of rent seeking corresponds closely to what might be called *corruption* of the agency.
- Assume second that the activities R_i, R_j are wasted, that is, rent seeking is negative-sum in nature. This case of rent seeking is more closely related to the common-sense interpretation of *lobbying*.

Comparing both types of rent seeking shows immediately that corruption ceteris paribus leads to a higher level of welfare because nothing is wasted. On the other hand, corruption is seen as morally condemnable and, therefore, is explicitly forbidden in almost every country.

5.1 Equilibrium strategies

The equilibrium strategies of the agency and of the sellers are the same for both types of rent seeking. Therefore, this subsection holds true for both corruption and

[16] For the modelling of rent-seeking contests see Dixit (1987), Baik and Shogren (1992) and Nitzan (1994).

[17] See Hillman and Riley (1989), Hillman and Samet (1987), Körber and Kolmar (1996), Nitzan (1994).

lobbying; their treatment need not be separated until it comes to the normative evaluation of the consequences of rent-seeking activities.[18]

At stage 3 the procurement agency announces the final contractor and signs a contract with this seller. We assume that the agency uses the following decision rule in order to determine the final contractor:

$$x(R_i, R_j) = \begin{cases} 1 & \text{if } R_i \geq R_j \\ 0 & \text{if } R_i < R_j \end{cases} \qquad (DR^*). \tag{18}$$

As will be shown shortly, this decision rule is part of a Nash equilibrium of the game. DR^* is based on the fact that R_k is higher, the higher the seller's quality: since the gross profit at stake, αq_k, is higher for the high-quality seller, in equilibrium he always spends more on rent seeking than the inferior-quality seller as we will prove shortly. Hence, $R_j > R_i$ reveals the information to the agency that $q_j > q_i$, so that the award should be revoked and the contract signed with the high-quality seller j.[19] Note that the winner i has the advantage that he will become the contractor if $R_i = R_j$. Hence, we have an asymmetric contest of the sellers.

It is plausible to assume a sequential bargaining structure at stage 2: the loser, who wants a revocation of the award, has to make the first move (stage 2a). The winner follows after observing the loser's rent-seeking activity (stage 2b). Both sellers anticipate the agency's decision rule DR^*. Applying backward induction, we calculate the sellers' optimal rent-seeking expenditures.

Stage 2b: The winner's profit $\pi_i(R_i, R_j)$ can be written as

$$\pi_i(R_i, R_j) = \begin{cases} \alpha q_i - R_i & \text{if } R_i \geq R_j \\ -R_i & \text{if } R_i < R_j \end{cases} . \tag{19}$$

The optimal strategy of the winner can be easily derived from this equation:

$$R_i^* = \begin{cases} R_j & \text{if } \alpha q_i \geq R_j \\ 0 & \text{if } \alpha q_i < R_j \end{cases} . \tag{20}$$

Stage 2a: The loser anticipates that the agency's decision rule would give him a profit $\pi_j(R_i, R_j)$:

$$\pi_j(R_i, R_j) = \begin{cases} \alpha q_j - R_j & \text{if } R_j > R_i \\ -R_j & \text{if } R_j \leq R_i \end{cases} . \tag{21}$$

[18] See subsections 5.2 and 5.3 below.

[19] The award-winning low-quality seller, in such a case, cannot sue the agency for compensation because his quality is not verifiable before a court or an arbitrator and he never enters stage 4 of the game where quality becomes verifiable.

However, since he cannot observe the winner's expenditures R_i, he can only find his own optimal expenditures by maximizing his expected profit Π_j:

$$\Pi_j = prob[R_j > R_i]\,\alpha q_j - R_j. \tag{22}$$

This expectation still contains the unobservable variable R_i. However, the loser's probability of winning the contest can be rewritten as follows. We know from the winner's reaction function that $prob[R_j > R_i] = prob[R_j > \alpha q_i] = F_i(R_j/\alpha)$. Therefore, the loser solves the following optimization problem:

$$\max_{R_j} \Pi_j = F_i(R_j/\alpha)\,\alpha q_j - R_j \tag{23}$$

under the restrictions that $R_j \geq 0$ and $F_i(R_j/\alpha)\,\alpha q_j - R_j \geq 0$. Appendix B gives a proof of the following lemma that characterizes the loser's optimal strategy:[20]

> **Lemma 4:** The loser's optimal strategy is either $R_j^* = 0$ or the optimum is characterized by $R_j^* > 0 \;\wedge\; f_i(R_j^*/\alpha)\,q_j = 1$.

The lemma is intuitive: whenever the loser engages in rent seeking, he will invest until the marginal return on investment is equal to the marginal costs. Marginal costs are equal to 1 whereas the marginal return on investment is equal to the increase in the probability of winning the contest $(1/\alpha)\,f_i(R_j/\alpha)$ times the gross profit αq_j.

In the following we have to distinguish between two cases: in the first, $R_j^* = 0$ is the equilibrium strategy for the loser. In this case, the winner always spends $R_i^* = 0$ and wins the contest. No information is revealed and the best the procurement agency can do is to stick to the DR^* strategy. Hence, a separation of award and contract is neutral with respect to the efficiency of the resulting allocation.

In the second case, $R_j^* > 0$ is the optimal strategy for the loser. For this case we prove the following lemma:

> **Lemma 5:** The loser has no incentive to overinvest, that is, $R_j^* \leq \alpha q_j$.

Proof: Assume to the contrary that $R_j^* > \alpha q_j$. In this case we have $\Pi_j = F_i(R_j^*/\alpha)\,\alpha q_j - R_j^* \leq \alpha q_j - R_j^* < 0$. However, this contradicts the assumption that R_j^* is a maximum, since the loser can always guarantee himself a zero profit by choosing $R_j = 0$. q.e.d.

[20] The problems of existence and uniqueness of an interior solution are qualitatively identical to those mentioned in footnote 11 for the case of negotiations. For details see Appendix B.

5.2 The case of a corrupt procurement agency

We are now in the position to prove the following result:

> **Result 7:** A separation of award and contract is efficiency-improving if rent-seeking activities have the character of corruption.

Proof: If $R_j^* = 0$, nothing changes compared to the situation where award and contract are not separated. If $R_j^* > 0$, we get

$$\begin{aligned} R_j^* &\leq \alpha q_j && \text{(loser's strategy)}, \\ R_i^* &= \begin{cases} R_j^* & \text{if } \alpha q_i \geq R_j^* \\ 0 & \text{if } \alpha q_i < R_j^* \end{cases} && \text{(winner's strategy)}. \end{aligned}$$

We have to prove the following statements: a) the award is revoked if and only if this is a change for the better; in other words, whenever the contract is signed with the loser, the loser has the higher quality, b) the procurement agency sticks to its strategy DR^* and c) there is a strictly positive probability that the award is revoked.

In order to prove a) we have to distinguish two cases:

1. $R_j^* > 0, R_i^* = 0$. In this case we have $\alpha q_j \geq R_j^* > \alpha q_i$ and, therefore, revoking the award is always a change for the better.

2. $R_j^* > 0, R_i^* = R_j^*$. In this case the award is never revoked.

We can therefore conclude that revoking the award always leads to an efficiency improvement. This implies immediately that DR^* is optimal for the procurement agency (which proves statement b). Finally, let us turn to the proof of statement c): what is the probability for the case $R_j^* > 0$ and $R_i^* = 0$? The first-order condition in lemma 4 allows the following explicit calculation of R_j^*:[21]

$$R_j^* = \alpha f_i^{-1}(1/q_j) =: \alpha\phi(q_j), \tag{24}$$

where $\phi(q_j)$ is a shorthand for $f_i^{-1}(1/q_j)$. Therefore, for given q_j the probability for $R_j^* > \alpha q_i$ is $prob\,[\alpha q_i < \alpha\phi(q_j)] = prob\,[q_i < \phi(q_j)] = F_i(\phi(q_j))$. Thus, the probability of an efficiency-improving revocation of the award is equal to

$$\int_{\underline{q}}^{\overline{q}} F_i(\phi(q_j))\, f_j(q_j) dq_j > 0. \tag{25}$$

This completes the proof of result 7. q.e.d.

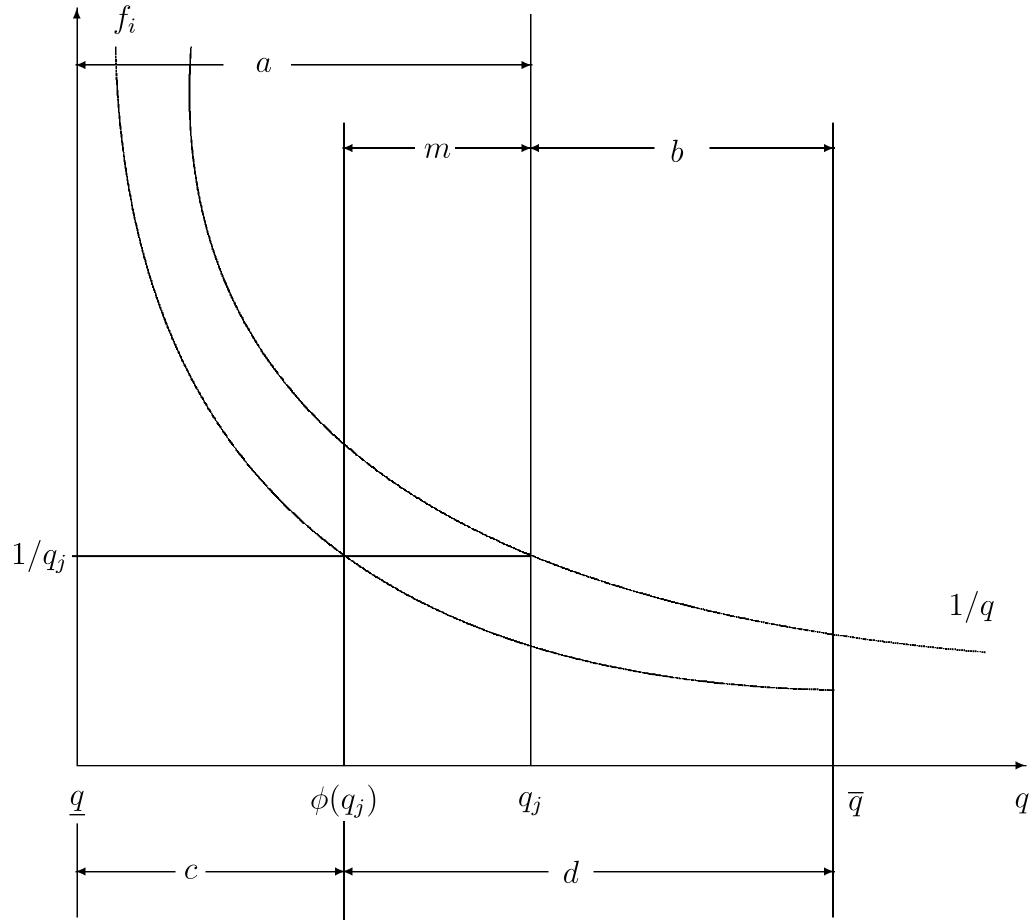

Figure 3: Efficiency-improving rent-seeking activities.

Figure 3, which is qualitatively similar to figure 2, illustrates the result. Again, a separation of award and contract improves upon the nonseparation if q_i lies in the interval c,[22] that is, if the loser is considerably better than the winner. If the difference between the sellers is small, the mechanism is unable to correct the initial error. The main intuition carries over from the case of negotiations: the creation of flexibility due to the separation of award and contract allows for the self-correction of imperfect decision rules, but only if the initial decision would have yielded substantial losses.

The result follows the same intuition as in the case of negotiations: the separation of award and contract successfully reduces the probability of decision errors if these errors would have implied relatively large losses. If, on the other hand, q_i and q_j are relatively close, the separation has no positive influence on the efficiency of the

[21]The inversion of the density function is well-defined because Π_j is strictly convex in an environment around R_j^*.

[22]The sellers' negotiations reverse the award if $\alpha q_j \geq \alpha\phi(q_j) > \alpha q_i \Leftrightarrow q_j \geq \phi(q_j) > q_i$.

allocation. The procurement agency's decision of whom to give the award therefore depends on the contingent expected value of the projects in the 'intermediate' ranges where the projects of both sellers have relatively similar qualities. Without giving a formal proof of this claim we can therefore conclude that there are cases for which it is reasonable for the procurement agency to give the award to the low-quality seller because his performance contingent on a restricted interval of q exceeds the performance of the other seller *despite the fact that his overall performance is worse.*

5.3 The case of lobbying

Let us finally turn to the analysis of rent-seeking contests where the investments are pure lobbying. The equilibrium strategies of the players are not affected by this change of interpretation, but the normative implications are. This is due to the fact that lobbying outlays are pure waste. We therefore have to calculate gains and losses explicitly.

The expected gain of a separation of award and contract is equal to the expected difference of the value of the game where award and contract are separated and the value of the game where award and contract are not separated, that is,

$$E[\Delta] = \int_{\underline{q}}^{\overline{q}} \left[F_i(\phi(q_j))\, q_j + \int_{\phi(q_j)}^{\overline{q}} q_i f_i(q_i) dq_i \right] f_j(q_j) dq_j - \int_{\underline{q}}^{\overline{q}} q_i f_i(q_i) dq_i. \tag{26}$$

The expected lobbying outlays for a given q_j, ΣR, are $\alpha\phi(q_j) + prob[\alpha q_i \geq \alpha\phi(q_j)]\alpha\phi(q_j)$. Recall that $prob[\alpha q_i \geq \alpha\phi(q_j)] = 1 - F_i(\phi(q_j))$. Therefore, the expected lobbying outlays are

$$E[\Sigma R] = \int_{\underline{q}}^{\overline{q}} \left[2 - F_i(\phi(q_j)) \right] \alpha\phi(q_j)\, f_j(q_j) dq_j. \tag{27}$$

If a separation of award and contract leads to lobbying activities of both sellers, the resulting equilibrium is efficiency-improving if

$$E[\Delta] - E[\Sigma R] > 0. \tag{28}$$

Substituting (26) and (27) reveals that this inequality is fulfilled if

$$\int_{\underline{q}}^{\overline{q}} \left[\underbrace{F_i(\phi(q_j))\, q_j}_{\geq 0} + \underbrace{\left[F_i(\phi(q_j)) - 2\right]\alpha\phi(q_j)}_{<0} - \underbrace{\int_{\underline{q}}^{\phi(q_j)} q_i f_i(q_i) dq_i}_{>0} \right] f_j(q_j) dq_j > 0.$$

Because of $0 \leq F_i(\cdot) \leq 1$, the first term is positive, and the second term negative. Thus, the effect on net profits is ambiguous, and we conclude as follows:

Result 8: In contrast to the case of corruption, a separation of award and contract is not necessarily efficiency-improving if rent-seeking activities have the character of lobbying.

6 Conclusion

The frequently used practice to separate award and contract in public procurement is a prominent example of what we have called *self-correcting mechanism*: the ex-ante imperfection of a procurement agency's decision can at least partly be offset because potential sellers obtain scope for negotiations or rent-seeking. It was shown that a separation of award and contract is efficiency-improving if the sellers can commit to the outcome of their negotiations or if the fraction of the total value of the public project that is wasted through the rent-seeking contest is not too large. However, it is unclear whether the welfare losses due to the degree of imperfection of negotiations or the welfare losses due to wasted lobbying outlays are worse.

Surprisingly, the expected public value of the project may be maximized if the award is given to a seller with an inferior quality signal. The intution for this result is as follows: negotiations or rent seeking will correct a wrong ex-ante decision if the quality of the award-winning seller is very low whereas the quality of the loser is very high. Thus, the expected payoffs of different awarding strategies differ only with respect to intermediate values of project quality. It can be the inferior seller who has a better contingent performance for these intermediate values despite the fact that his unconditional expected value for product quality is below that of the other seller.

Summarizing, we obtained a relatively robust result with respect to the efficiency-improving effects of self-correcting mechanisms, regardless of whether the agents use the time-span between award and contract for negotations, lobbying, or even corruption.

Appendix A

Proof of result 5

The procurement agency should choose $s_G = i$ if and only if

$$G(i) - G(j) \geq 0. \tag{1}$$

We will now consider an example that demonstrates that both $s_G = i$ and $s_G = j$ may be optimal if $e_i > e_j$. Let $q \in [0, 1]$ be the support of the value of the project and $F_k(q) = q^{e_k}, k = i, j$, be the class of admissible distribution functions with associated density functions $f_k(q) = e_k q^{e_k - 1}, k = i, j$, for $e_k \in (0, \infty)$.

We will first compute the optimal offers of the losing sellers in the post-award negotiation game. Inserting the above density and distribution functions into (7) we get

$$\frac{1}{\alpha} e_i \frac{p_j}{\alpha}^{e_i - 1} (\alpha q_j - p_j) - \frac{p_j}{\alpha}^{e_i} = 0. \tag{2}$$

Solving for p_j yields

$$p_j = \alpha \frac{e_i}{1 + e_i} q_j, \tag{3}$$

and analogously for p_i. The contingent expected values of giving the award to i and j, respectively, are as follows:

$$G(i) = \beta\mu_i + \beta \int_{\underline{q}}^{\overline{q}} F_i(p(q_j/\alpha) q_j f_j(q_j) dq_j - \beta \int_{\underline{q}}^{\overline{q}} \int_{\underline{q}}^{\frac{p(q_j)}{\alpha}} q f_i(q) dq f_j(q_j) dq_j$$

and

$$G(j) = \beta\mu_j + \beta \int_{\underline{q}}^{\overline{q}} F_j(p(q_i/\alpha) q_i f_i(q_i) dq_i - \beta \int_{\underline{q}}^{\overline{q}} \int_{\underline{q}}^{\frac{p(q_i)}{\alpha}} q f_j(q) dq f_i(q_i) dq_i.$$

Inserting (3) and substituting for the density and distribution functions yields

$$G(i) = \beta \left[\mu_i + \frac{(\alpha\mu_i)^{e_i} e_j}{1 + e_i + e_j} - \frac{\alpha^{1+e_i} \mu_i^{e_i + 2}}{e_i + 2} \right]$$

and

$$G(j) = \beta \left[\mu_j + \frac{(\alpha\mu_j)^{e_j} e_i}{1 + e_j + e_i} - \frac{\alpha^{1+e_j} \mu_j^{e_j + 2}}{e_j + 2} \right].$$

We denote by ΔG the difference $[G(i) - G(j)]/\beta$. First, we calculate this difference for $e_j = 1$, thus $\mu_j = 1/2$, and $e_i \to \infty$. Since $\lim_{e_i \to \infty} \mu_i = 1$ and $\lim_{e_i \to \infty} \mu_i^{e_i} = 1/\mathrm{e}$, where e is Euler's number, we obtain

$$\begin{aligned} \Delta G &= (1 - 1/2) + \lim_{e_i \to \infty} \frac{0 \cdot 1/\mathrm{e} \cdot 1 - \alpha \cdot 1/2 \cdot e_i}{2 + e_i} - \frac{0 \cdot 1/\mathrm{e}}{2 + \infty} + \frac{\alpha^2 \cdot (1/2)^3}{3} \\ &= \frac{12 + \alpha^2}{24} - \lim_{e_i \to \infty} \frac{(1/2)\alpha e_i}{2 + e_i} \\ &= \frac{12 - 12\alpha + \alpha^2}{24} > 0, \end{aligned} \tag{4}$$

because $\alpha \in [0, 1]$.

Second, we calculate the above difference for $e_i = 1$, thus $\mu_i = 1/2$, and $e_j \to 0$. Since $\lim_{e_j \to 0} \mu_j = 0$ we obtain

$$\begin{aligned} \Delta G &= (1/2 - 0) + \frac{\alpha \cdot 1/2 \cdot 0 - 1 \cdot 1 \cdot 1}{2} - \frac{\alpha^2 \cdot (1/2)^3}{3} + \frac{1 \cdot 0^2}{2} \\ &= -\frac{\alpha^2}{24} < 0. \end{aligned} \tag{5}$$

By the intermediate-value theorem there is a nonempty subset $\{\underline{e}_j, \overline{e}_j\} \in (0, \infty)$ and a critical value $e_i^{crit} \in (0, \infty)$ for every $e_j \in \{\underline{e}_j, \overline{e}_j\}$ such that for all values of e_i above e_i^{crit} the award should be given to the seller with the inferior signal and vice versa. q.e.d.

Appendix B

Proof of lemma 4

The Lagrangean of the loser, seller j, is

$$\mathcal{L} = F_i(R_j/\alpha)\,\alpha q_j - R_j + \lambda R_j + \mu\left(F_i(R_j/\alpha)\,\alpha q_j - R_j\right), \tag{1}$$

which yields the following Kuhn-Tucker first-order conditions:

$$\begin{aligned} R_j &: \quad (1+\mu)\left(f_i(R_j/\alpha)\,q_j - 1\right) + \lambda \leq 0 \ \wedge\ R_j \geq 0 \\ &\quad\ \ \wedge\ R_j\left((1+\mu)\left(f_i(R_j/\alpha)\,q_j - 1\right) + \lambda\right) = 0, & (2) \\ \lambda &: \quad R_j \geq 0 \ \wedge\ \lambda \geq 0 \wedge \lambda R_j = 0, & (3) \\ \mu &: \quad F_i(R_j/\alpha)\,\alpha q_j - R_j \geq 0 \ \wedge\ \mu \geq 0 \ \wedge\ \mu\left(F_i(R_j/\alpha)\,\alpha q_j - R_j\right) = 0. & (4) \end{aligned}$$

These conditions give rise to 3^3 possible cases which in turn have to be analyzed. There are two qualitatively different types of solutions that have to be distinguished: First, $R_j = 0$ may turn out to be optimal. This leads directly to part 1 of lemma 4 irrespective of the specification of parameter values. Second, $R_j > 0$ may turn out to be optimal. Then $f_i(R_j/\alpha)\,q_j - 1 = 0$ has to be fulfilled. Note that this result holds both for interior and for corner solutions. For $R_j > 0$, conditions (2) require $(1+\mu)\left(f_i(R_j/\alpha)q_j - 1\right) = 0$,[23] and since $\mu \geq 0$, this always implies $f_i(R_j/\alpha)\,q_j - 1 = 0$, regardless of whether we have an interior solution where $F_i(R_j/\alpha)\,\alpha q_j - R_j \geq 0$ is not binding ($\mu = 0$), or we have a corner solution where $F_i(R_j/\alpha)\,\alpha q_j - R_j = 0$, and $\mu > 0$. q.e.d.

[23] $\lambda = 0$ in this case, as can be seen from conditions (3).

Technical details

Since the winner's density function enters the first-order condition $f_i(R_j^*/\alpha)\, q_j = 1$, it is not guaranteed that the Kuhn-Tucker conditions characterize a unique maximum. Due to its lack of structure the condition might characterize a local minimum and even if it characterizes a maximum, it need not be unique. In order to characterize a local maximum we need $(1/\alpha)\, f_i'(R_j^*/\alpha)\, q_j \leq 0$ at R_j^*. Fortunately, we do not require existence or uniqueness of an interior solution in this context. All we need is $R_j^* > 0 \;\wedge\; f_i(R_j^*/\alpha)\, q_j = 1$ for every local maximum. If there are several ones, we will use the convention that the loser chooses that with the highest expected profit Π_j.

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