Corruption-proof Contracts in Competitive Procurement

Preliminary Version

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Abstract

Public authorities are typically concerned with quality but lack the skills to appraise the technical aspects of sophisticated goods they wish to procure. Therefore, they need to rely on the assessment made by a third party, the auctioneer, creating room for corruption attempts by the competing firms. If verifiable signals correlated with quality are *ex-post* available, the public authority can obtain a high-quality good through a signal-contingent contract in which the awarded firm receives stochastic payments.

In this paper, we present a corruption-proof auction that makes the auctioneer accountable for her report and induces truthful reporting even when there are no exogenous limit to evidence manipulation. If competing firms are risk-neutral, the corruption-proof auction outperforms the signal-contingent contract provided that the country's institutions are strong enough. If competing firms are risk-averse, this condition may no longer be necessary. Finally, we show that the profitability of the corruption-proof auction increases in the number of firms (*competition effect*).

1 Introduction

Price is not the only key variable that a buyer may want to consider when he awards a procurement contract. The quality of the infrastructures or of the services provided typically plays a crucial role in the final decision.

Cases where quality features are of primary importance to the buyers can be found, for example, in the provision of education, health-care, and transportation services which are more and more commonly delivered through Private Finance Initiative.

However, the buyer may lack the skills needed to evaluate the technical proposals and as a result he needs to rely on the assessment made by an external expert, that

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we call the auctioneer. The procurement literature recommends to lower the weight of quality relative to price in the scoring rule whenever the subjectivity of the assessment creates room for corruption (Burguet and Che, 2004). This is because it is believed that corruption cannot be properly addressed in presence of information which cannot be substantiated (see Tirole, 1986, Laffont and Tirole, 1991, and Lengwiler and Wolfstetter, 2006).

In contrast to the previous literature, in this paper we find that it is possible to prevent corruption in procurement auctions where there is a quality concern and the auctioneer's report is based on soft-information. In particular, we do not impose any exogenous limit to the ability of the auctioneer to manipulate her appraisal of the technical proposals to favor a specific firm. Namely, the report is based on *purely-soft information*. This result is obtained by making the auctioneer effectively accountable for her report.

We develop a model where a public authority (the buyer[1]) wishes to procure a good from the outside and he cares about its quality which he cannot observe ex-ante and cannot verify ex-post. For the sake of simplicity, we assume that quality can take only two values, that is, it can be either high or low. It would be socially optimal to produce high quality, even if it entails a higher cost of production. We assume that there are two interested risk-neutral and wealth constrained contractors who bear different costs to deliver the good.

The buyer holds an auction to award the contract as he is unable to distinguish between the two producers. If the auctioneer's assessment is based on purely-soft information, the buyer cannot obtain a reliable report by paying her a fixed compensation. Therefore, the proposals can be compared only on the price dimension and the firm who is the most efficient in producing low quality is awarded the contract.

As a matter of fact, once the goods are produced or the services are provided, signals imperfectly correlated with quality become available. Practical examples of such signals are customer satisfaction surveys and recognition of excellence awarded by independent organizations to schools, hospitals, etc. Particularly important, in this respect, is the experience of the now defunct CABE (The Commission for Architecture and the Built Environment) which was in charge of assessing the quality design of public infrastructures in the UK. It issued several reports wherein the buildings were typically evaluated according to the Design Quality Indicator[2]. Through this toolkit, buildings are assessed on the basis of their *functionality* (design), *build quality* (the building fabric), and *impact* (the building's ability to create a sense of place and affect positively the local community and environment). Moreover, quality infrastructure indicators are widely employed to determine the contractors' compensation (see Iossa and Martimort, 2012). These performance measures inform the buyer about the quality of the good and can be contracted upon since they are verifiable.

In the model, we show that the auctioneer can be induced to reveal truthfully the observed quality of the project proposals by anchoring her compensation to

[1]In the paper, we will use the two terms interchangeably.

[2]See, for example, the report on secondary schools (CABE, 2006), and on health-care facilities (CABE, 2008).

the alignment between the report and the signal. To prevent the auctioneer from misreporting quality, the buyer must impose the corruption incentive compatibility constraints that properly address both bribery and extortion. Bribery occurs when a bidder approaches the auctioneer to send the buyer his preferred report on quality in exchange for a monetary transfer. Framing/extortion takes place when the auctioneer threatens the bidder who should be awarded the contract to misreport quality if he refuses to transfer her a substantial amount of money. Unlike Khalil et al. (2010), we prove that bribery and extortion can be simultaneously addressed in presence of information which can be manipulated at no cost by the auctioneer alone[3].

As it deters corruption, our suggested mechanism implies that the weight placed on quality in the scoring rule does not need to be reduced and the buyer is better off than under an auction based solely on price.

The availability of ex-post verifiable signals correlated with quality also paves the way for a more canonical solution to the asymmetric information problem. Rather than hiring an auctioneer to appraise the technical proposals, the buyer may promise the contractor payments contingent on the realization of the signal. Henceforth, we refer to this solution as the *signal-contingent contract*. The existence of limited liability constraints implies that the contractor cannot be punished when the signal realization is low and, as a result, it may be very expensive to implement such contingent contract. Nevertheless, this solution provides a lower bound to the utility the public authority can attain.

The public authority will find it advantageous to hold the auction when it is not overly costly to deter corruption. Therefore, the role of the institutions in fighting corruption plays a prominent role in our model. We measure the strength of the institutions by the probability $(1-\beta)$ of discovering the corruption attempt undertaken by the auctioneer-bidder coalition. This parameter captures the effectiveness of the monitoring technologies as well as other factors which may reduce the probability that corruption is successful. These other factors[4] may include the uneasiness of enforcing the side-contract and psychological costs associated with being involved in illegal activities[5].

Provided that the institutions are sufficiently strong, the corruption-proof auction dominates the signal-contingent contract and its benefits for the public authority increase in the probability of detecting corruption. When the corruption-proof auction is adopted, the auctioneer is made accountable for her report and her reward is inversely correlated with the institutional strength. If the institutional framework is such that it is too costly to hire the auctioneer, the signal-contingent contract represents a viable alternative. If we assume that the interested contractors are risk-averse, the advantages of the corruption-proof auction increase as it perfectly

[3]In their paper, Khalil et al. (2010) consider a hierarchical organization consisting of a principal, a supervisor, and an agent. They argue that it may be optimal to allow a certain amount of bribery, while extortion must always be prevented, since the latter acts as a punishment after a good behavior: the agent must pay the supervisor not to hide positive evidence.

[4]There exists a large body of literature on the transaction costs of side-contracting . Some foundations are provided in Martimort (1999).

[5]Psychological costs are expected to be higher when the institutional framework is stronger.

insures the awardee, whereas the signal-contingent contract does not. Therefore, the corruption-proof auction may be the optimal award mechanism regardless of the institutional strength.

These results are reminiscent of Iossa and Martimort (2011) who analyze the relationship between the strength of the institutions and the extent to which ex-post risk is transferred to a contractor. Similarly, the authors find that the lower the quality of the institutions, the higher the risk borne by the contractor in the optimal incentive contract.

Finally, we show how a tougher competition on the supply-side affects the buyer's choice of the award mechanism. In particular, it turns out that a higher number of firms reduces the price required by the contractor to deliver the good only in the corruption-proof auction setting. Moreover, it reduces the cost of preventing corruption, lowering the incentives of the bidders to bribe the auctioneer. This *competition effect* increases the desirability of adopting the auction mechanism.

The rest of the paper is organized as follows. Section 2 presents our model. Section 3 develops the corruption-proof auction and shows the expected cost to the buyer of achieving a high-quality good when a corruptible auctioneer is hired. Section 4 considers the signal-contingent contract and shows under what condition the buyer prefers to hold the corruption-proof auction. Section 5 deals with the risk aversion of the firms. Section 6 studies the impact of competition on the choice of the screening-device and highlights the existence of the competition effect. Section 7 concludes.

2 The model

A risk neutral public authority (the buyer) wishes to procure a good from the outside. There are two different specifications of the good, which differ with respect to quality and production costs. We assume that the quality, q, can take only two values, $q \in \{\bar{q}, \underline{q}\}$, with $\bar{q} > \underline{q}$, which enters the utility function of the buyer linearly.

There are two potential contractors, a and b, protected with limited liability. Irrespective of the contractor, it is more costly to produce high than low quality, that is, $c_i(\bar{q}) > c_j(\underline{q})$, for $i, j = a, b$. Henceforth, we assume that the bidders are specialized in delivering different project specification[6]. In particular, a has a competitive advantage in producing high quality, $c_a(\bar{q}) < c_b(\bar{q})$, while bidder b bears a lower cost of production for low quality, $c_a(\underline{q}) > c_b(\underline{q})$. A noteworthy implication of this assumption is that $\Delta c_b(q) > \Delta c_a(q)$, where $\Delta c_i(q) = c_i(\bar{q}) - c_i(\underline{q})$ for $i = a, b$. In general, it would be socially optimal to allocate the contract to firm a to produce a high-quality good and it would be more efficient to obtain high rather than low quality. Initially we assume that the contractors are risk-neutral. In Section 5, we relax this assumption and we study the implications of risk aversion on the optimal award mechanism.

Whilst the buyer does not distinguish the identities of the two firms, each firm does. As a result, each firm knows both his own production costs and those of

[6] We take into account other possibilities in the Appendix A. Nevertheless, the case considered in the text is, in our opinion, the most intriguing.

his competitor. This assumption allows us to focus on the corruption side of the procurement auction rather than on the bidding behavior of the firms in a setting characterized by uncertainty about the bidders' types.

When a project proposal is submitted for evaluation (*ex-ante*), the buyer is unable to assess its quality, while *ex-post* quality can be observed but not verified. Therefore, it is not possible to sign an enforceable contract contingent on quality. However, once the good is realized, a verifiable signal s correlated with quality is drawn. This signal can take two values $s \in \{l, h\}$; if $q = \bar{q}$ (respectively $q = \underline{q}$), then s takes value h (l) with probability $\gamma > 1/2$.

The buyer is unable to distinguish between the two firms but we assume that he knows the distribution of costs of each project specification[7]. Since he cannot observe quality, the simplest evaluation of offers involves solely a comparison of the transfers requested by the bidders. In this case, the bidder who asks for the lowest price receives a non-negative monetary transfer t to deliver the good. In this case, it would be firm b to be awarded the contract.

Nevertheless, the existence of a verifiable signal sets the stage for two further possibilities. First, the buyer can hire an external expert, the auctioneer, who can costlessly observe the quality of the proposals at the bidding stage. The auctioneer is risk-neutral and wealth-constrained. She draws up a report on the technical aspects of the two projects and receives a payment w which is contingent on both the report and the signal s. Specifically, $w \in \{\bar{w}_h, \bar{w}_l, \underline{w}_h, \underline{w}_l\}$ where the upper and lower bars refer to the quality reported by the auctioneer and the subscript refers to the signal realization. Before sending her report to the buyer, the auctioneer can make a side-contract with either bidder. In the side-contract, the auctioneer promises to report the quality of the two proposals according with the needs of the colluding bidder in exchange for a bribe which is paid once the contract is awarded.

We assume that there exists an exogenous probability $(1 - \beta)$ that corruption is detected by the judicial authorities. When this occurs, the side-contract is ineffective. As already said in the introduction, $(1 - \beta)$ is intended to capture the fact that collusion may not be successful. We treat this parameter as exogenous and we argue that it is strictly related to the strength of the institutions. These are typically endowed with better monitoring technologies which increase the probability of discovering the corruption attempt. However, strong institutions may make it more difficult for the parties to collude for further reasons. For instance, they may reflect a collective attitude towards honest behaviors.

Theoretically the buyer may also dispense with the auctioneer and pay the contractor signal-contingent transfers. In particular, he may set the transfers he is willing to pay for any realization of the signal. This alternative approach will represent the benchmark with which we will compare the corruption-proof auction outcome.

[7]As the distribution is binomial, the buyer knows the cost that the bidders incur to deliver high and low quality. What he does not know is the identity of each bidder.

3 A corruption-proof auction

We describe our auction mechanism explicitly taking into account the possibility that the auctioneer may attempt to distort the auction outcome to favor a bribing bidder. The timing of events when the auctioneer is hired is as follows:

1. Bidders submit their bids which consist of a requested price and a technical offer;
2. the auctioneer observes the proposals and the bidders compete in bribes to obtain the auctioneer's favor;
3. the auctioneer sends a report on the quality of the two proposals to the buyer;
4. the buyer compares the two bids and selects the highest score. The winning bidder receives the asked price;
5. the good is delivered;
6. the signal is drawn and the auctioneer receives a transfer.

Note that the buyer is reluctant to pay more than $c_b(\bar{q})$ (respectively, $c_a(\underline{q})$) to obtain high (low) quality. Therefore, he will rationally set a ceiling to the maximum price he is willing to pay for any project specification.The bids are represented by a pair $(\hat{q}_i, t_i)$, for $i \in \{a, b\}$ where $\hat{q}_i$ is the quality announced by the auctioneer for bidder i. The contract is awarded to the bidder whose bid maximizes the linear scoring rule set by the buyer: $S_i = \hat{q}_i - t_i$, for $i \in \{a, b\}$.

If the auctioneer were incorruptible or if the institutions were so strong that any corruption attempt was always detected (that is, $\beta = 0$), there would be no side-contracting stage and bidder a would win the auction by submitting a bid $(\bar{q}, c_b(\bar{q}))$. Thanks to the information asymmetry, bidder a would thus attain a positive profit: $\pi_a = c_b(\bar{q}) - c_a(\bar{q})$. The buyer's payoff would be $\bar{q} - c_b(\bar{q})$. The auctioneer does not need to be paid as she does not exert effort to assess the proposals, whereas bidder b receives a null profit.

If $\beta > 0$ and the auctioneer is corruptible, she must be induced to reveal truthfully the quality of the proposals. With purely-soft information, the auctioneer's report cannot be substantiated and, as a result, the bidders are tempted to bribe her to misreport the quality of the proposals. If corruption succeeds, the buyer obtains a low-quality good for a high-quality price.

Unlike other papers in this literature in which the auctioneer may favor an exogenous bidder (see Laffont and Tirole, 1991 and Celentani and Ganuza, 2002), here we assume that the auctioneer can write a side-contract with either bidder. Bidders will compete in bribes and the firm who can offer the most will approach the auctioneer. The bribe is then paid only if the auctioneer succeeds in steering the contract to the bribing bidder. The next two propositions show the constraints that need to be imposed to prevent corruption and the supervisor's optimal contingent payments.

Proposition 1. *Any corruption attempt fails whenever the following corruption incentive compatibility constraints hold:*

$$E[\underline{w}|q_b = \underline{q}, \hat{q}_b = \underline{q}] \geq E[\bar{w}, \beta\Delta c_b|q_b = \underline{q}, \hat{q}_b = \bar{q}] \qquad \text{(CIC1)}$$

$$E[\bar{w}|q_a = \bar{q}, \hat{q}_a = \bar{q}] \geq E[\underline{w}, \beta\Delta\underline{c}|q_a = \bar{q}, \hat{q}_a = \underline{q}], \tag{CIC2}$$

where $\Delta\underline{c} = c_a(\underline{q}) - c_b(\underline{q})$.

Proof. First, notice that the constraints can be rewritten as follows:

$$\gamma\underline{w}_l + (1-\gamma)\underline{w}_h \geq \gamma\bar{w}_l + (1-\gamma)\bar{w}_h + \beta\Delta c_b \tag{CIC1}$$

$$\gamma\bar{w}_h + (1-\gamma)\bar{w}_l \geq \gamma\underline{w}_l + (1-\gamma)\underline{w}_h + \beta\underbrace{[c_a(\underline{q}) - c_b(\underline{q})]}_{\Delta\underline{c}} \tag{CIC2}$$

Both firms would be willing to deliver a low-quality good for a high-quality price. However, it is bidder b who can offer the auctioneer the most to over-report the quality of his proposal and to underreport the quality of a's. In fact, the maximum bribe that a can promise is $c_b(\bar{q}) - c_a(\underline{q})$ which is lower than b's maximum bribe, Δc_b, since $c_a(\underline{q}) > c_b(\underline{q})$. If bidder a expects the quality of his proposal to be underreported, he will submit low quality. However, constraint (CIC1) implies that the expected utility of the auctioneer given $q_b = \underline{q}$ is higher when she truthfully reports $\hat{q}_b = \underline{q}$ than when she reports $\hat{q}_b = \bar{q}$.

Once (CIC1) holds, bidder b still has an incentive to bribe the auctioneer to underreport a's quality. The maximum bribe b is able to offer is $c_a(\underline{q}) - c_b(\underline{q}) = \Delta\underline{c}$. To deter this kind of corruption, the buyer must impose constraint (CIC2).

When this condition is fulfilled, bidder a knows that he does not run the risk of having the quality of his proposal underreported. In addition, constraint (CIC1) also deters bidder a from submitting a low-quality proposal and bribing the auctioneer to report $\hat{q}_a = \bar{q}$. As a result, a will submit $q_a = \bar{q}$.

On the other hand, the auctioneer could threaten a to underreport the quality of his project and/or to over-report the quality of his competitor's proposal unless he transfer her a positive amount of money (*extortion/framing*[8]). However, the threat of underreporting quality is implausible when $\gamma\bar{w}_h + (1-\gamma)\bar{w}_l \geq \gamma\underline{w}_l + (1-\gamma)\underline{w}_h$. In this case, if bidder a rejects the deal, the auctioneer finds it advantageous to truthfully report a's quality. Notice that such an extortion threat is always prevented when constraint (CIC2) holds.

The other extortion threat, wherein the auctioneer threatens a to pay her not to over-report b's quality, is incredible as well. If a rejects the deal, the auctioneer is not induced to misreport b's quality, for it would lower her expected payoff because of constraint (CIC1).

Finally, a never finds it profitable to reduce b's quality, since the assumption on Δq implies that the latter can never obtain a score higher than that of a, $S_a = \bar{q} - c_b(\bar{q})$. □

[8] We define extortion as the payment the auctioneer obtains from the winning bidder by threatening him to misreport evidence. Framing occurs when the extortion attempt fails and the auctioneer effectively puts into practice her threat. A firm will accept the extortion agreement only if framing is sequentially rational for the auctioneer. For further details, see Khalil et al. (2010).

Proposition 2. *Given the supervisor's limited liability, the optimal payment scheme which satisfies (CIC1) and (CIC2) entails the following contingent transfers:*

$$w^* = \begin{cases} \underline{w}_l^* = \frac{\beta\left[\frac{(1-\gamma)}{\gamma}\Delta\underline{c}+\Delta c_b\right]}{(2\gamma-1)}, \\ \bar{w}_h^* = \frac{\beta[\Delta\underline{c}+\Delta c_b]}{(2\gamma-1)}, \\ \underline{w}_h^* = \bar{w}_l^* = 0. \end{cases}$$

Proof. See the appendix. □

Proposition 2 says that if the quality of the selected project has been reported to be high (respectively, low), the auctioneer receives a positive payment if and only if h (l) realizes. In other words, the auctioneer receives a positive payment if and only if the realized signal s is the most aligned with the quality reported for the winning bidder.

Once the optimal payment scheme is implemented, backward induction arguments lead a to submit a bid $(\bar{q}, c_b(\bar{q}) - \varepsilon)$, where ε can be taken arbitrarily small, b to submit a bid $(\bar{q}, c_b(\bar{q}))$ and the auctioneer to report truthfully.

As a result, a wins the auction and the buyer's total expected cost of achieving a high-quality good is:

$$E[T|A] = \gamma \frac{\beta}{(2\gamma-1)}[\Delta\underline{c} + \Delta c_b] + c_b(\bar{q}). \quad (1)$$

The above equation shows that there exists a negative relationship between the strength of the institutional framework and the cost of implementing the corruption-proof auction. In particular, when the institutions are such that corruption is not always detected, the auctioneer must be rewarded when her report is aligned with the observed signal. In addition, the weaker the institutions (formally, the higher the β), the larger the auctioneer's compensations that ensure truthful reporting. However, it must be stressed that even when $\beta = 1$ the public authority manages to effectively deter corruption and thereby to achieve a high-quality good.

Finally, we need to make a remark on the side-contracting stage between the bribing bidder and the auctioneer. The allocation of all the bargaining power to the auctioneer is due to the nature of the side-contracting game. If the buyer did not set the constraints as if the auctioneer held all the bargaining power, corruption would not be prevented. For any different distribution of the bargaining powers, the bribing bidder may relinquish a tiny fraction of his bargaining power and strike a mutually beneficial agreement with the auctioneer. Therefore, corruption is prevented if only if the buyer considers the tightest conceivable constraints.

4 A signal-contingent contract

Theoretically, there exists an alternative solution wherein the buyer neither runs an auction nor hires an external expert to assess the quality of the proposals. In the auction setting, the signals are employed to induce truthfully reporting by rewarding the auctioneer for quality announcements which are more reliable. However, the selected contractor may as well receive stochastic payments which are contingent on the signal realization. One advantage of this alternative approach is that the buyer can save the payment due to the auctioneer. On the other hand, the buyer must cope with the agency problem and with the limited liability of the contractors.

The timing of moves changes substantially:

1. the buyer announces $\bar{t}$ and $\underline{t}$, that is, the contingent transfers he will pay to the selected contractor;
2. the interested contractors may either accept or reject the offer. If only one of them accepts, he is automatically chosen as the contractor. If both accept, the awardee is randomly chosen;
3. the good is delivered;
4. the signal is drawn and the contractor receives a transfer.

With such a signal-contingent contract, the problem of the buyer is to determine the transfers $\bar{t}$ and $\underline{t}$ in such a way that he achieves a high-quality good. In particular, the transfers must ensure (i) the participation of at least the most efficient firm in delivering high-quality and (ii) that none of the potential contractors finds it profitable to deliver $q = \underline{q}$. Condition (i) implies that

$$\gamma \bar{t} + (1-\gamma)\underline{t} \geq \min_{i \in \{a,b\}} c_i(\bar{q}) \tag{PC}$$

which is the participation constraint of the most efficient firm in delivering high quality. Condition (ii) entails

$$(2\gamma - 1)[\bar{t} - \underline{t}] \geq \max_{i \in \{a,b\}} \Delta c_i \tag{IC}$$

which is the incentive compatibility constraint of the firm whose cost differential to deliver high and low quality is the largest[9]. Given our assumptions on the production costs of the two firms, the two above constraints can be rewritten as follows:

$$\gamma \bar{t} + (1-\gamma)\underline{t} \geq c_a(\bar{q})$$

as a is the most efficient firm in producing high-quality and

$$(2\gamma - 1)[\bar{t} - \underline{t}] \geq \Delta c_b$$

since $\Delta c_a < \Delta c_b$.

When $\Delta c_b < \frac{c_a(\bar{q})(2\gamma-1)}{\gamma}$, both (PC) and (IC) bind at the optimum. Therefore, $\bar{t}$ and $\underline{t}$ are strictly positive and equal to the following expressions.

$$\bar{t} = c_a(\bar{q}) + \frac{1-\gamma}{2\gamma-1}\Delta c_b$$

$$\underline{t} = c_a(\bar{q}) - \frac{\gamma}{2\gamma-1}\Delta c_b$$

[9] While the reason why we impose the first constraint is straightforward, the logic behind the second constraint might be less intuitive. Notice that when the transfers are set in such a way that a is willing to participate (i.e., the first constraint holds), b may be willing to participate and deliver a low quality good unless the second constraint is not introduced.

In this case, only a accepts the buyer's offer to deliver the high-quality good while b's participation constraint is not satisfied. The expected cost to the buyer is $c_a(\bar{q})$ which is always lower than the expected cost of implementing the corruption-proof auction.

When $\Delta c_b > \frac{c_a(\bar{q})(2\gamma-1)}{\gamma}$, the non-negativity constraint associated with $\underline{t}$ binds. As a result, $\underline{t}$ is optimally set equal to zero while $\bar{t} = \frac{\Delta c_b}{2\gamma-1}$. Therefore, the expected cost of achieving high quality is $E[T|scc] = \frac{\gamma}{2\gamma-1}\Delta c_b$. The following proposition shows under what condition the corruption-proof auction dominates the signal-contingent contract:

Proposition 3. *The buyer prefers to run the corruption-proof auction if and only if*

$$\beta \leq \frac{\Delta c_b - \frac{(2\gamma-1)}{\gamma}c_b(\bar{q})}{\Delta \underline{c} + \Delta c_b} = \beta^*$$

Proof. The proof can be found in Appendix B. □

Notice that a necessary condition for β^* to be non-negative is that $\Delta c_b \geq \frac{(2\gamma-1)}{\gamma}c_b(\bar{q})$, which is the condition needed for b to participate. In particular, $\beta^* = 0$ when b's participation constraint binds. Put differently, when b's participation constraint binds, an auction yields the buyer the same outcome as the signal-contingent contract if the probability that the corruption attempt fails is 1. It is worthwhile noticing that $\beta^* < 1$.

In general, we can conclude that if Δc_b is sufficiently low, only a accepts the signal-contingent contract offered by the buyer. If so, what can be seen as the standard solution to an agency problem always dominates the corruption-proof auction. If Δc_b is sufficiently high, both firms accept the contract proposed by the buyer. Indeed, the signal-contingent contact does not allow the buyer to identify the most efficient firm. It is in this case that the auction mechanism may improve upon the signal-contingent contract. In practice, this occurs whenever the institutional framework is strong enough to ensure a non-negligible probability that the auctioneer and the bribing bidder will be caught if they try to manipulate the auction outcome.

Proposition 2 also suggests that when institutions are sufficiently strong, a corruption-proof auction may profitably be implemented. When this happens, the auctioneer bears the ex-post risk associated with the imperfect alignment between quality and its signal. On the other hand, when institutions are weak, it could be too costly to deter corruption in an auction where there are quality concerns. Adopting the signal-contingent contract, the ex-post risk is transferred to the contractor who should not receive any payment larger than $\underline{t}$ before the realization of the signal. This clearly raises the question of whether the presence of risk-averse firms will make it more advantageous to turn to an auction mechanism. We investigate this issue in the following Section.

5 The effect of risk aversion

In the signal-contingent contract analyzed in Section 4, the contractor does not receive any upfront payment before delivering the good[10]. Rather, he will receive a stochastic payment only later on, depending on the realization of the quality signal.

As long as firms are risk-neutral and they have no difficulty covering the production cost (or the financial markets work properly), the uncertainty about the payments does not matter. Nevertheless, risk neutrality is a restrictive assumption and, as often assumed elsewhere in this literature, firms may be risk averse. This is due to scale of PPP projects, which often take a large fraction of the firms's activities.

By contrast, the auctioneer may be able to share risk better than a firm, by building a portfolio consisting of negatively correlated projects. Moreover, she bear quality-detection costs which are typically negligible when compared to the production costs.

Therefore, it is of particular interest to study how risk aversion impacts on the payments required by firms to deliver high-quality goods. Thus, in this section we assume that each firm's preferences are described by a strictly concave utility function. Since firms working in the same industry may have similar attitudes towards risk, we assume that both firms share the same CARA utility function:

$$u(t) = \frac{1}{r}\left[1 - e^{-r(t-c)}\right]$$

where r is the Arrow-Pratt coefficient of absolute risk aversion. In this case, the corruption-proof auction becomes *ceteris paribus* more advantageous than the signal-contingent contract as the former provides full insurance to the contractor while the latter gives rise to the usual trade-off between action efficiency and insurance cost.

What changes with respect to the case previously examined are the transfers paid by the buyer in the signal-contingent contract and thereby $[E|scc]$. Since the expected cost of implementing the corruption-proof auction does not change with respect to the risk neutral bidders case, we can calculate the usual threshold β_r^*[11]:

$$\beta_r^* = \frac{(2\gamma-1)}{\gamma}\frac{E[T|scc] - c_b(\bar{q})}{\Delta c_b + \Delta \underline{c}},$$

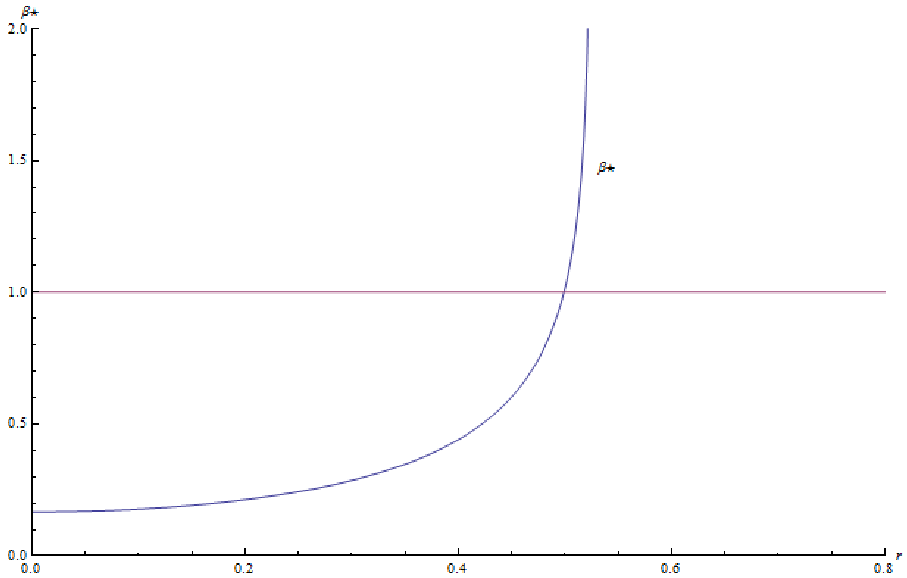
where $E[T|scc]$ is monotonically increasing in the contractor's risk aversion.

In Figure 1 we present an illustrative example which provides some insights on how β^* evolves as a function of the contractors' risk aversion. In particular, we assume the following parametrization: $\gamma = 0.75$, $c_b(\bar{q}) = 2.6$, $c_b(\underline{q}) = 0.5$, $c_a(\bar{q}) = 2.5$ and $c_a(\underline{q}) = 0.6$. Notice that for $r \geq 0.5$, β^* is strictly greater than 1, meaning that even if corruption is never to be detected, it is optimal to award the contract through the corruption-proof auction rather than through the signal-contingent contract. Moreover, for slightly greater values of r, the only way for the buyer to achieve high quality is to run the corruption-proof auction.

[10] Alternatively, we may think that an upfront payment of $\underline{t}$ is received when the good is delivered, but this can occur only if Δc_b is small enough.

[11] The signal-contingent transfers are shown in Appendix C.

Figure 1: β^* as a function of r



This simple numerical exercise highlights an important feature of our model. Under contractors' risk aversion, the corruption-proof auction can dominate the signal-contingent contract even if institutions are totally unable to detect corruption attempts (i.e., $\beta = 1$). Conversely, when contractors are risk neutral, β^* is always smaller than one. In addition, the buyer can always achieve the high-quality good through the corruption-proof auction whereas it can be shown that the cost of insuring the contractor under the signal-contingent contract explodes when r grows above a certain threshold.

6 Multiple firms and the competition effect

Thus far we have considered the simplest case where there are only two interested contractors. The aim of this Section is to generalize our mechanism to a situation where there are $n > 2$ risk-neutral firms competing for the contract. We reach a similar condition on the threshold β under which the corruption-proof auction dominates the signal-contingent contract. In addition, this analysis will allow us to highlight the effect of competition on the choice of the optimal screening device.

Each firm i can provide both high-quality and low-quality projects and is characterized by a vector of production costs $c_i = \{c_i(\underline{q}), c_i(\bar{q})\}$, with $c_i(\underline{q}) < c_i(\bar{q})$ for each $i \in \{1, ..., n\}$. For the sake of simplicity, we assume that firm i is strictly more efficient than any firm $j > i$ and strictly less efficient than any firm $f < i$ in delivering high quality, i.e., $c_1(\bar{q}) < c_2(\bar{q}) < ... < c_n(\bar{q})$. On the other hand, we assume that each firm i is strictly less efficient than any firm $j > i$ and strictly more efficient than any firm $f < i$ in delivering low quality, i.e., $c_1(\underline{q}) > c_2(\underline{q}) > ... > c_n(\bar{q})$. As a consequence, the cost differential are monotonically increasing in the firm identity, that is $\Delta c_1 < \Delta c_2 < ... < \Delta c_n$.

Following the same reasoning as in Section 3, the buyer can prevent any form of corruption by setting the following constraints:

$$\gamma \underline{w}_l + (1-\gamma)\underline{w}_h \geq \gamma \bar{w}_l + (1-\gamma)\bar{w}_h + \beta \Delta c_n \tag{MCIC1}$$

$$\gamma \bar{w}_h + (1-\gamma)\bar{w}_l \geq \gamma \underline{w}_l + (1-\gamma)\underline{w}_h + \beta \Delta \underline{c}_{n-1,n} \tag{MCIC2}$$

where $\Delta \underline{c}_{n-1,n} = c_{n-1}(\underline{q}) - c_n(\underline{q})$. Now, bidder n enjoys a competitive advantage in bribing the auctioneer when no constraints are set. Therefore, constraint (MCIC1) must be imposed to prevent him from bribing the auctioneer to report $\hat{q}_n = \bar{q}$ and $\hat{q}_j = \underline{q}$ for all $j \neq n$. Once (MCIC1) holds, bidder n can still find it profitable to bribe the auctioneer to obtain $\hat{q}_j = \underline{q}$ for all $j \in \{1, ..., n\}$ and pay her the net profit ($\Delta \underline{c}_{n-1,n}$) he could earn in light of his competitive advantage in low-quality production. The auctioneer never finds it advantageous to accept such a deal whenever constraint (MCIC2) is satisfied. As in the 2-bidders case, (MCIC1) and (MCIC2) prevent any form of extortion.

Solving the system consisting of (MCIC1) and (MCIC2), both considered with the equality sign, straightforward algebra leads to the following contingent transfers necessary to induce truthful reporting:

$$\underline{w}_l^* = \frac{\beta}{2\gamma - 1}\left[\frac{(1-\gamma)\Delta \underline{c}_{n-1,n}}{\gamma} + \Delta c_n\right]$$

$$\bar{w}_h^* = \frac{\beta}{2\gamma - 1}\left[\Delta \underline{c}_{n-1,n} + \Delta c_n\right]$$

$$\bar{w}_l^* = \underline{w}_h^* = 0$$

Once truthful reporting is ensured, each bidder is better off submitting a high-quality project proposal. As a result, bidder 1 wins the auction and receives a price $t_1 = c_2(\bar{q})$, which is the maximum price he can obtain from the buyer. Therefore, the buyer expected cost is represented by:

$$E[T|A] = \gamma \frac{\beta}{2\gamma - 1}\left[\Delta \underline{c}_{n-1,n} + \Delta c_n\right] + c_2(\bar{q}).$$

With respect to the 2-bidders case, there is a *competition effect* on the price received by the winning bidder, who does not obtain the price ceiling but the second lowest high-quality production cost. Whereas, the cost differential of firm n, Δc_n, only matters for the corruption-proof payments that are due to the auctioneer.

The *competition effect* does not arise when the buyer considers the signal-contingent contract. When deciding whether to implement this alternative solution, the buyer should provide the right incentives to make each firm willing to produce high-quality rather than low-quality. This implies that the *incentive compatibility* constraint of firm n must bind. On the other hand, as the buyer wants to induce the participation of at least one firm, the *participation constraint* of the most efficient firm (1) must always be fulfilled[12]. Formally, $\underline{t}$ and $\bar{t}$ must be such that the following system is satisfied:

[12]Both constraints are a modified version of the constraints presented in Section 3

$$\gamma\bar{t} + (1-\gamma)\underline{t} \geq c_1(\bar{q}) \tag{PC1}$$

$$(2\gamma - 1)[\bar{t} - \underline{t}] \geq \Delta c_n \tag{ICn}$$

We need to distinguish between two cases:

(i) If $\Delta c_n < \frac{(2\gamma-1)c_1(\bar{q})}{\gamma}$, i's participation constraint and n's incentive compatibility constraint bind at the optimum. As a result, we have $\underline{t} = c_1(\bar{q}) + \frac{(1-\gamma)\Delta c_n}{2\gamma-1}$ and $\bar{t} = c_1(\bar{q}) - \frac{\gamma\Delta c_n}{2\gamma-1}$. Therefore, $E[T|scc] = c_1(\bar{q}) < E[T|A]$ for all $\gamma \in (1/2, 1]$.

(ii) If $\Delta c_n \geq \frac{(2\gamma-1)c_1(\bar{q})}{\gamma}$, the non-negativity constraint associated with $\underline{t}$ binds. As a result, at the optimum we have $\underline{t} = 0$ and $\bar{t} = \frac{\Delta c_n}{2\gamma-1}$. Therefore, the expected cost of implementing the contingent contract, $E[T|scc] = \gamma\frac{\Delta c_n}{2\gamma-1}$, depends solely on the signal precision γ and on the cost differential of firm n, while the buyer does not benefit from the competition among potential contractors.

The expected cost of the corruption-proof auction is smaller than the expected cost of the signal-contingent contract whenever the following condition holds:

$$\beta \leq \frac{\Delta c_n - \frac{c_2(\bar{q})(2\gamma-1)}{\gamma}}{\Delta c_n + \Delta \underline{c}_{n-1,n}} = \beta_n^*. \tag{2}$$

What is the expected effect of an increase in the number of interested contracts? To provide an intuition, let us assume that, for each contractor, production costs are randomly drawn from two uniform distributions, defined over intervals $[\underline{c}(\underline{q}), \bar{c}(\underline{q})]$ and $[\underline{c}(\bar{q}), \bar{c}(\bar{q})]$ for the low-quality project and the high-quality project, respectively.

Let us rewrite $\beta^* = \frac{N}{D}$, where $N = \Delta c_n - \frac{c_2(\bar{q})(2\gamma-1)}{\gamma}$ and $D = \Delta c_n + \Delta \underline{c}_{n-1,n}$.

If n rises, the variation in β_n^*, that we call $\Delta\beta_n^*$, is positive if and only if $\Delta N - \Delta D$ is positive. Since a change in Δc_n has the same impact on both N and D, this change does not have any impact on β_n^*. On the other hand, given the assumption on cost distributions, the expected variation of $\frac{c_2(\bar{q})(2\gamma-1)}{\gamma}$ and the expected variation of $\Delta \underline{c}_{n-1,n}$ are both negative.

Consequently, $\Delta\beta_n^* > 0$ for any $n < \infty$, and the expected effect of an increase in the number of competitors is to rise the benefits of the corruption-proof auction (*competition effect*).

7 Concluding remarks

Corruption is a widespread phenomenon in procurement. The problem is particularly pressing at the tender stage when firms compete to be awarded the contract and the buyer has a quality concern. Firms may be tempted to offer bribes to the person or the organization in charge of assessing the different proposals, the auctioneer, to win her favor. The problem is compounded when the auctioneer's appraisal cannot be substantiated as this feature facilitates the misreport of the quality of the technical proposals.

In this article we have shown how to develop an auction mechanism which deters corruption even when there are no limit to the ability of the auctioneer to misreport quality. To do so, we have made the auctioneer accountable for the content of her report in such a way that she is better off truthfully announcing the observed quality. We have also investigated the role played by both the institutional strength and the risk aversion on the choice of the optimal award mechanism. We have thereby highlighted how countries in which institutions are weaker should *ceteris paribus* transfer more risk from the auctioneer to the contractor. Seen from this perspective, our paper shares some ideas with Iossa and Martimort (2011) who focus on the corruption taking place at the implementation stage and analyze the relationship between the quality of the institutions and the allocation of risk.

Our mechanism could be fruitfully applied to the so-called Private Finance Initiative model in which the contractor is paid by the public authority to provide a service which does not generate revenues (e.g., hospitals, prisons, schools). There, the quality of the infrastructure or of the service tends to be the chief concern of the buyer. Nonetheless, it may be difficult to discriminate between project proposals at the tender stage and, at the same time, corruption may be alluring as the value of the contracts is typically very large.

The prescription of our model is to pay a considerable fraction of the auctioneer's compensation in the form of variable pay which is tied to the alignment of her report with the realization of a verifiable signal of quality. In addition, we recommend the collection of reliable data on the quality of the infrastructures and of the services provided. These data, which represent the signal we refer to throughout the analysis, must be a piece of hard information. To this end, the organization in charge of evaluating the performance ex-post must be autonomous and independent of both the buyer, who would have an incentive to downplay the quality of the good, and the auctioneer, who would be willing to over-rate quality. A clear distinction between the roles of the different players is thus necessary to achieve the desired outcome.

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Appendix: Proof of Proposition 2

The buyer minimizes the expected payments to the auctioneer subject to the (CIC1), (CIC2), and the non-negativity constraints associated with the contingent payments, $\bar{w}_s, \underline{w}_s \geq 0$ for $s \in \{h, l\}$.

To simultaneously satisfy (CIC1) and (CIC2), no more than two non-negativity constraints can bind. Furthermore, reporting a given quality level cannot be a dominant strategy for the auctioneer, namely, truthful revealing cannot be induced if $\bar{w}_s = 0$ or $\underline{w}_s = 0$ for any $s \in \{h, l\}$. Therefore, a necessary condition for a payment scheme to induce truthful reporting is to have at least one positive contingent transfer for each possible reported quality level.

In general, $\bar{w}_h$ (respectively, $\underline{w}_l$) is the contingent payment that has the highest probability to be received by the auctioneer when she truthfully reports $q = \bar{q}$ ($q = \underline{q}$). As a result, we claim that a solution wherein $\bar{w}_l = \underline{w}_h = 0$ and (CIC1), (CIC2) are binding is the optimal one. To show this claim hold true, we need to check for four conceivable combinations:

1. $\underline{w}_l = \bar{w}_h = 0$;
2. $\underline{w}_h = \bar{w}_h = 0$;
3. $\underline{w}_l = \bar{w}_l = 0$;
4. $\underline{w}_h = \bar{w}_l = 0$;

In what follows, we will check for these four combinations.

1. If $\underline{w}_l = \bar{w}_h = 0$, constraints (CIC1) and (CIC2) can be rewritten as follows:

$$(1-\gamma)\underline{w}_h \geq \gamma \bar{w}_l + \beta \Delta c_b;$$

$$(1-\gamma)\bar{w}_l \geq (1-\gamma)\underline{w}_h + \beta \Delta \underline{c}.$$

By solving this system, we find that $\underline{w}_h = \frac{\beta}{1-2\gamma}\left[\frac{\Delta \underline{c}}{1-\gamma} + \Delta c_b\right]$ which violates the non-negativity constraints associated with $\underline{w}_h$. As a result, the pair $\underline{w}_l = \bar{w}_h = 0$ cannot be part of any truthful-reporting payment-scheme.

2. If $\underline{w}_h = \bar{w}_h = 0$, constraints (CIC1) and (CIC2) can be rewritten as follows:

$$\gamma \underline{w}_l \geq \gamma \bar{w}_l + \beta \Delta c_b;$$

$$(1-\gamma)\bar{w}_l \geq \gamma \underline{w}_l + \beta \Delta \underline{c}.$$

Using simple algebra we find that the solution $\underline{w}_l = \frac{\beta}{\gamma(1-2\gamma)}\left[\Delta \underline{c} + \Delta c_b(1-\gamma)\right]$ violates the non-negativity constraints associated with $\underline{w}_l$. Therefore, the pair $\underline{w}_h = \bar{w}_h = 0$ cannot be part of any truthful-reporting payment-scheme.

3. If $\underline{w}_l = \bar{w}_l = 0$, constraints (CIC1) and (CIC2) can be rewritten as follows:

$$(1-\gamma)\underline{w}_h \geq (1-\gamma)\bar{w}_h + \beta \Delta c_b;$$

$$\gamma \bar{w}_h \geq (1-\gamma)\underline{w}_h + \beta \Delta \underline{c}.$$

The pair $\bar{w}_h = \frac{\beta[3\gamma\Delta \underline{c} + \Delta c_b]}{(2\gamma-1)}$, $\underline{w}_h = \frac{\beta\gamma}{(2\gamma-1)}\left[\Delta \underline{c} + \frac{\Delta c_b}{1-\gamma}\right]$ represents a solution for this system when both inequalities bind. Once truthful reporting is ensured, the probability that a high-quality proposal is implemented is one. As a result, the expected transfers paid to the auctioneer is equal to $\frac{\gamma\beta[3\gamma\Delta \underline{c} + \Delta c_b]}{(2\gamma-1)}$.

4. If $\underline{w}_h = \bar{w}_l = 0$, constraints (CIC1) and (CIC2) can be rewritten as follows:

$$\gamma \underline{w}_l \geq (1-\gamma)\bar{w}_h + \beta \Delta c_b;$$

$$\gamma \bar{w}_h \geq \gamma \underline{w}_l + \beta \Delta \underline{c}.$$

The pair $\bar{w}_h = \frac{\beta[\Delta \underline{c} + \Delta c_b]}{(2\gamma-1)}$, $\underline{w}_l = \frac{\beta\left[\frac{(1-\gamma)}{\gamma}\Delta \underline{c} + \Delta c_b\right]}{(2\gamma-1)}$ represents a solution for this system when both inequalities bind. In this case, the expected transfers paid to the auctioneer is equal to $\frac{\gamma\beta[\Delta c_b + \Delta \underline{c}]}{(2\gamma-1)}$.

It can be easily seen that the expected transfer paid to the auctioneer at point 3 is strictly higher than that at point 4 whenver $\Delta \underline{c} > 0$.

□

Appendix A: different cost specifications

Thus far we have analyzed a setting where bidder b has the highest cost differential ($\Delta c_b > \Delta c_a$) and each bidder is specialized in the production of one quality level. Specifically, we have assumed that bidder b has a competitive advantage in delivering low quality while bidder a has a competitive advantage in delivering high quality.

Although the production specialization assumed thus far is the most plausible situation in the real world, there are several industries where one firm is always more efficient then its competitors[13].

[13]In their contribution, Burguet and Che (2004) also assume that one firm is the most efficient in delivering any possible quality specification.

In what follows, we consider four different cases as a function of the *production costs of the two bidders*, of the *cost differentials within bidders* ($\Delta c_i = c_i(\bar{q}) - c_i(\underline{q})$, for $i = a, b$) and the *cost differential within quality levels* ($\Delta\bar{c} = |c_b(\bar{q}) - c_a(\bar{q})|$ and $\Delta\underline{c} = |c_b(\underline{q}) - c_a(\underline{q})|$). Without loss of generality, henceforth we keep the assumption that a is always more efficient than b in delivering high quality.

If the cost differential Δc_b is greater than Δc_a, we need to analyze the two following cases:

- **Case 1:** $\Delta c_b > \Delta c_a$, $c_a(\underline{q}) < c_b(\underline{q})$, $\Delta\bar{c} > \Delta\underline{c}$;
- **Case 2:** $\Delta c_b > \Delta c_a$, $c_a(\underline{q}) < c_b(\underline{q})$, $\Delta\bar{c} < \Delta\underline{c}$.

On the other hand, $\Delta c_b < \Delta c_a$ implies that $c_a(\underline{q}) < c_b(\underline{q})$ for any $c_b(\bar{q}) > c_a(\underline{q})$. As a result, we need to consider two further cases:

- **Case 3:** $\Delta c_b < \Delta c_a$, $c_a(\underline{q}) < c_b(\underline{q})$, $\Delta\bar{c} > \Delta\underline{c}$;
- **Case 4:** $\Delta c_b < \Delta c_a$, $c_a(\underline{q}) < c_b(\underline{q})$, $\Delta\bar{c} < \Delta\underline{c}$.

For each of these situations, we show that there exists a threshold β_i^* for $i = 1, 2, 3, 4$ under which the corruption-proof auction dominates the signal-contingent contract. In addition, it is possible to show that $\beta_i^* = 0$ if and only if $\max_{j=a,b} \Delta c_j = \frac{c_b(\bar{q})(2\gamma-1)}{\gamma}$.

Case 1

In Case 1, any b's attempt to bribe the auctioneer to obtain $\hat{q}_b = \bar{q}$ while $q_b = \underline{q}$ cannot succeed once constraint (CIC1) is satisfied. Moreover, since a has a cost advantage in producing low quality, it is not rational for b to bribe the auctioneer to report $\hat{q}_a = \underline{q}$, cause also in this situation a's would win the auction by submitting $q_a = \underline{q}$ and $p_a = c_b(\underline{q}) - \varepsilon_{\to 0}$.

However, a can always try to bribe the auctioneer to obtain $\hat{q}_a = \bar{q}$ while $q_a = \underline{q}$ to increase his profit. To prevent such an agreement, we need to impose

$$\gamma\underline{w} \geq (1-\gamma)\bar{w} + \beta[c_b(\bar{q}) - c_a(\underline{q})] \qquad \text{(CIC1.1)}$$

Notice that (CIC1) is automatically satisfied once (CIC1.1) binds.

Finally, to induce truthful reporting we need to impose the usual *extortion incentive compatibility* constraint

$$\bar{w} \geq \underline{w}$$

which along with constraint (CIC1.1) leads to the following payment scheme

$$\bar{w} = \frac{\beta}{(2\gamma-1)}[c_b(\bar{q}) - c_a(\underline{q})] = \underline{w}$$

Through arguments similar to those used to prove Proposition 2, it can be shown that the corruption-proof auction dominates the side-contingent contract whenever the following condition is satisfied.

$$\beta \leq \frac{\Delta c_b - \frac{(2\gamma-1)}{\gamma}c_b(\bar{q})}{c_b(\bar{q}) - c_a(\underline{q})} = \beta_1^*.$$

Case 2

Let us focus on Case 2. We are exactly in the same situation as Case 1 but, since $\Delta\bar{c} < \Delta\underline{c}$, the potential profits of a are higher when delivering low quality than when delivering high quality. As a result, the buyer wants to discourage a situation in which a submits a low quality project and the auctioneer reports ($\hat{q}_a = \underline{q}$) and ($\hat{q}_b = \underline{q}$) irrespective of the quality of the project submitted by b. As a payment for this reporting, a transfers the extra-profit $\Delta\underline{c} - \Delta\bar{c}$ to the auctioneer.

To prevent this collusive agreement, the buyer has to impose the following *corruption incentive compatibility* constraint:

$$\gamma\bar{w} \geq \gamma\underline{w} + \beta[\Delta\underline{c} - \Delta\bar{c}] \tag{CIC2.1}$$

Once (CIC2.1) is satisfied, the extortion-incentive compatibility constraint is slack. As a result, the auctioneer's payment scheme is determined by solving the system composed by constraint (CIC1.1) and constraint (CIC2.1), whose solution is represented by the following equations

$$\underline{w} = \frac{\beta}{(2\gamma - 1)}\left[\frac{(1-\gamma)}{\gamma}[\Delta\underline{c} - \Delta\bar{c}] + c_b(\bar{q}) - c_a(\underline{q})\right]$$

$$\begin{aligned}\bar{w} &= \frac{\beta}{(2\gamma - 1)}\left[\Delta\underline{c} - \Delta\bar{c} + c_b(\bar{q}) - c_a(\underline{q})\right]\\ &= \frac{\beta}{(2\gamma - 1)}\left[\Delta c_a + \Delta\underline{c}\right]\end{aligned}$$

Again, the corruption-proof auction dominates the signal-contingent contract provided that the institutional framework is strong enough, that is when:

$$\beta \leq \frac{\Delta c_b - \frac{c_b(\bar{q})(2\gamma-1)}{\gamma}}{\Delta c_a + \Delta\underline{c}} = \beta_2^*.$$

The signal-contingent contract when $\Delta c_b < \Delta c_a$

Before considering cases 3 and 4, we need to determine the *signal-contingent contract* transfers once $\Delta c_b < \Delta c_a$. As done in the text, we have to take into account the a's *participation* and *incentive compatibility* constraints, since now a is the bidder with the lowest high quality cost as well as the bidder with the highest cost differential.

This leads to the following *signal-contingent payment rule*

$$\bar{t} = c_a(\bar{q}) + \frac{(1-\gamma)\Delta c_a}{(2\gamma - 1)}$$

$$\underline{t} = c_a(\bar{q}) - \frac{\gamma\Delta c_a}{(2\gamma - 1)}$$

As in the previous case, the $\underline{t}$'s limited liability constraint binds ($\underline{t}$=0) if and only if $\Delta c_a > \frac{c_a(\bar{q})(2\gamma-1)}{\gamma}$.

It's easy to see that b's is willing to participate if and only if $\Delta c_a \geq \frac{c_b(\bar{q})(2\gamma-1)}{\gamma}$.

Case 3

Since a has a cost advantage in delivering both quality levels, the only way b can win the auction is by inducing the reporting $\hat{q}_a = \underline{q}$ and $\hat{q}_b = \bar{q}$. To obtain this reporting, the maximum bribe b is able to pay is $\beta\Delta c_b$. To prevent this form of corruption, it sufficient to set:

$$\gamma\underline{w} \geq (1-\gamma)\bar{w} + \beta\Delta c_b \tag{CIC3.1}$$

When constraint (CIC3.1) is satisfied, the auctioneer does not find it worthwhile to overestimate b's quality.

When this is the case, b has no chance to win the auction, cause a has a cost advantage in delivering both quality levels.

On the other hand, under (CIC3.1) a still has an incentive to bribe the auctioneer to report $\hat{q}_a = \bar{q}$ while $q_a = \underline{q}$. This collusive agreement is prevented when the following constraint is set:

$$\gamma\underline{w} \geq (1-\gamma)\bar{w} + \beta[c_b(\bar{q}) - c_a(\underline{q})] \tag{CIC3.2}$$

where $[c_b(\bar{q}) - c_a(\underline{q})]$ is the highest bribe that a can afford to pay. Notice that (CIC3.1) is slack when (CIC3.2) binds cause $c_a(\underline{q}) < c_b(\underline{q})$ by assumption.

Finally, to avoid any extortion attempt, we need to set the usual *extortion incentive compatibility* constraint:

$$\bar{w} \geq \underline{w}$$

The extortion incentive compatibility constraint and (CIC3.2) are the two relevant constraints to determine the auctioneer's compensation. In particular, the buyer proposes the following compensation scheme to the auctioneer:

$$\bar{w} = \frac{\beta}{(2\gamma-1)}[c_b(\bar{q}) - c_a(\underline{q})] = \underline{w}$$

This implies the following expected cost of implementing the corruption-proof auction

$$E[T|A] = \gamma\frac{\beta}{(2\gamma-1)}[c_b(\bar{q}) - c_a(\underline{q})] + c_b(\bar{q})$$

that we have to compare with the expected cost of implementing the signal-contingent solution:

$$E[T|scc] = \gamma\frac{\Delta c_a}{(2\gamma-1)}$$

As usual, we can find a β_3^* such that the corruption-proof auction outperforms the signal-contingent contract for all $\beta < \beta_3^*$, that is:

$$\beta_3^* = \frac{\Delta c_a - \frac{c_b(\bar{q}\gamma)(2\gamma-1)}{\gamma}}{c_b(\bar{q}) - c_a(\underline{q})}$$

Case 4

Let us finally consider Case 4. Here, the potential profits of a are higher when delivering low quality than when delivering high quality ($\Delta\bar{c} < \Delta\underline{c}$).

Therefore, we are exactly in the same situation as Case 3, but now the buyer wants to discourage a situation in which a submits a low quality project and the auctioneer reports ($\hat{q}_a = \underline{q}$) and ($\hat{q}_b = \underline{q}$) irrespective of the quality of the project submitted by b. As a payment for this reporting, the auctioneer receives the extra-profit $\Delta\underline{c} - \Delta\bar{c}$.

To prevent such a deal, the buyer sets the following constraint:

$$\gamma\bar{w} \geq \gamma\underline{w} + \beta[\Delta\underline{c} - \Delta\bar{c}] \tag{CIC4.1}$$

Whenever (CIC4.1) is satisfied, the extortion-incentive compatibility constraint is slack. The auctioneer's payment scheme is determined as the solution of the system made up by the equality version of (CIC3.2) and (CIC4.1). As a result, we obtain:

$$\underline{w} = \frac{\beta}{(2\gamma - 1)} \left[\frac{(1-\gamma)}{\gamma} [\Delta\underline{c} - \Delta\bar{c}] + c_b(\bar{q}) - c_a(\underline{q}) \right]$$

$$\begin{aligned}\bar{w} &= \frac{\beta}{(2\gamma - 1)} \left[\Delta\underline{c} - \Delta\bar{c} + c_b(\bar{q}) - c_a(\underline{q}) \right] \\ &= \frac{\beta}{(2\gamma - 1)} [\Delta c_a + \Delta\underline{c}]\end{aligned}$$

Again, the corruption-proof auction proofs superior to the signal-contingent contract if and only if:

$$\beta \leq \frac{\Delta c_a - \frac{c_b(\bar{q})(2\gamma-1)}{\gamma}}{\Delta c_a + \Delta\underline{c}} = \beta_4^*.$$

Appendix B: Proof of Proposition 2

By sequential rationality arguments, the buyer will choose to implement the screening-device whose expected costs are the smallest possible. Therefore, we need to find the values of β such that $E[T|A] \leq E[T|scc]$, that is:

$$E[T|A] = \gamma\frac{\beta}{(2\gamma - 1)}[\Delta\underline{c} + \Delta c_b] + c_b(\bar{q}) \leq \frac{\gamma\Delta c_b}{(2\gamma - 1)} = E[T|scc].$$

By subtracting $c_b(\bar{q})$ from both sides and then by multiplying by $\frac{(2\gamma-1)}{\gamma}$ both sides we obtain:

$$\beta[\Delta\underline{c} + \Delta c_b] \leq \Delta c_b - \frac{(2\gamma - 1)c_b(\bar{q})}{\gamma}.$$

Finally, by dividing both sides by $[\Delta\underline{c} + \Delta c_b]$ we obtain the result shown in Proposition 2, i.e.,

$$\beta \leq \frac{\Delta c_b - \frac{(2\gamma-1)c_b(\bar{q})}{\gamma}}{\Delta \underline{c} + \Delta c_b}.$$

□

Appendix C: the case of risk aversion

Given the assumption made on the utility function, we can rewrite the a's participation constraint and b's incentive compatibility constraint as follows:

$$\gamma\left[1 - e^{-r[\bar{t}-c_a(\bar{q})]}\right] + (1-\gamma)\left[1 - e^{-r[\underline{t}-c_a(\bar{q})]}\right] \geq 0 \qquad \text{(PC)}$$

$$\begin{aligned}&\gamma\left[1 - e^{-r[\bar{t}-c_b(\bar{q})]}\right] + (1-\gamma)\left[1 - e^{-r[\underline{t}-c_b(\bar{q})]}\right] \geq \\ &\gamma\left[1 - e^{-r[\underline{t}-c_b(\underline{q})]}\right] + (1-\gamma)\left[1 - e^{-r[\bar{t}-c_b(\bar{q})]}\right]\end{aligned} \qquad \text{(IC)}$$

The solution to the buyer's problem implies that:

$$\bar{t} = \frac{1}{r}\ln\left[\frac{(1-\gamma)e^{rc_b(\underline{q})} - \gamma e^{rc_b(\bar{q})}}{[(1-\gamma)e^{rc_b(\bar{q})} - \gamma e^{rc_b(\underline{q})}]e^{-r\underline{t}}}\right]$$

and

$$\underline{t} = \frac{1}{r}\ln\left[\gamma\frac{(1-\gamma)e^{rc_b(\bar{q})} - \gamma e^{rc_b(\underline{q})}}{(1-\gamma)e^{rc_b(\underline{q})} - \gamma e^{rc_b(\bar{q})}} + (1-\gamma)e^{rc_a(\bar{q})}\right]$$

whenever $\gamma\frac{(1-\gamma)e^{rc_b(\bar{q})} - \gamma e^{rc_b(\underline{q})}}{(1-\gamma)e^{rc_b(\underline{q})} - \gamma e^{rc_b(\bar{q})}} + (1-\gamma)e^{rc_a(\bar{q})} > 1$.
On the other hand, we obtain:

$$\bar{t} = \frac{1}{r}\ln\left[\frac{(1-\gamma)e^{rc_b(\underline{q})} - \gamma e^{rc_b(\bar{q})}}{(1-\gamma)e^{rc_b(\bar{q})} - \gamma e^{rc_b(\underline{q})}}\right]$$

and

$$\underline{t} = 0$$

elsewhere.