Holding an Auction for the Wrong Project[*]

Alessandro De Chiara - ECARES[†]

Abstract

How does the probability of being involved in a renegotiation during the execution of a procurement contract affect the behavior of the agents? What are its implications for the optimal contractual choice made by the principal? This paper investigates these issues in a context characterized by uncertainty about the adequateness of the project initially specified by the buyer. The main result of this paper establishes that, in several circumstances, the buyer may find it profitable to hold an auction for the project design which ex-ante does not have the higher probability of being appropriate, that is, it is wrong.

Keywords: Procurement, Asymmetric Auctions, Renegotiation, Bargaining under Asymmetric Information.

1 Introduction

Contracts concerning the provision of customized goods or services are often granted through auctions. In particular, in many countries the rules which govern the purchases of the public sector prescribe that a competitive procedure must be undertaken to award such contracts. In the United States, the Federal Acquisition Regulations clearly recommends the federal agencies to employ auctions (*sealed bids*) rather than negotiations (*competitive proposals*) when they acquire goods and services[1]. It is claimed that an auction guarantees transparency and fosters competition, allowing the buyer to elicit the most favorable price conditions. Nonetheless, once awarded, a number of procurement contracts undergo substantial modifications and these changes do not only involve the final cost of the good or the time of delivery, but they also significantly alter the design itself of the project. Moreover, in a lot of occurrences the events which trigger the revision of the original agreements could have been predicted at the time of drawing up the initial contract[2].

If a renegotiation significantly alters the scale and the scope of the original contract, one may cast doubts over the optimality of the outcome stemming from the auction process. It may occur

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[†]PhD Student at the European Center for Advanced Research in Economics and Statistics (ECARES), Université Libre de Bruxelles, Avenue F.D. Roosevelt 50, CP114, 1050 Bruxelles (Belgium). Phone: +32 2 650 3373. E-mail: aledechiara@gmail.com. I am particularly indebted to my supervisor Patrick Legros for his constant support and for his insightful comments and suggestions. I am also grateful to Luca Livio and Guido Maretto for their helpful comments and observations. The usual disclaimers apply.

[1]See *https://www.acquisition.gov/Far/current/pdf/FAR.pdf*

[2]In this regard, Guasch (2004) provides extensive empirical evidence of strategic renegotiation of concession contracts granted in Latin America and the Caribbean in the period 1985-2000.

that a firm suitable to provide the original service is no longer the most appropriate operator when the contract is reviewed. Nevertheless, contract clauses may prevent (or just may make it unprofitable) the buyer from turning to another firm for the provision of the service.

A compelling example involves the fledging community bicycle industry. The two top competitors are the French company JC Decaux and the American firm Clear Channel. The former was recently awarded two controversial contracts by the city of Paris and by the region of Brussels, in 2007 and 2008, respectively. In France, the contract was soon extended to cover a much broader area while, in Belgium, JC Decaux had been already providing the service in the Brussels municipality at the time of the auction of the regional contract, raising the suspicion that he took advantage of his dominant position to win the broader contract. Until then, JC Decaux had only run the service in small towns, unlike Clear Channel who had been already providing similar services in Barcelona (2007), Stockholm (2006) and Oslo.

In this paper, we consider a situation where there is uncertainty over the design of a project that a buyer wishes to procure. Specifically, we assume that there are two alternative specifications of the good, A and A' and the prior probability that the design A turns out to be flawed, if implemented, is $\beta \in (0, 1)$, which is common knowledge to all the players of the game.

In our setting there are only two potential contractors and the buyer has already decided to hold an auction to select the awardee. Moreover, we assume that the bidders are specialized in delivering one specification of the project each and, as a consequence, its alternative designs entail different production costs. In particular, we assume that the relative cost advantage enjoyed by one bidder in undertaking project A is reversed when it is the alternative project specification to be carried out.

The question we want to address is whether it is always profitable for the buyer to hold an auction for the project specification which has the lowest probability of being flawed. If not, under which conditions is the procurer better off when he holds a competitive tender for the project design which is more likely to be inappropriate? In addition, to which extent is this decision affected by the relative bargaining power of the parties?

2 The Model

Consider a risk-neutral government who wishes to procure a good from the outside and works out on his own its design, say A[3], to which he attaches a positive value, v, and pays the contractor a fee b:

$$U = v - b$$

Nonetheless, if the initial design A proves unsuitable, then the project yields the buyer utility:

$$v - h > 0$$

if it is not modified. Whereas, if a change in the building phase occurs and the alternative design A' is adopted, the buyer again attains utility v. However, the new project requires different capabilities from the engaged contractor and it may thus entail either a higher or a lower cost of production. Henceforth, we assume that once the tender process has taken place, the buyer is stuck to the selected contractor and cannot hire the other firm (in practice, one

[3] The results will not change if we assume that he contracts out the delivery of the alternative project specification A', though.

may think of a large cost of breaching the initial contract which makes it unprofitable for the buyer to go back on his initial choice).

Bidders are risk neutral and, as mentioned earlier, have different project design specialization. In particular, we assume that when A is carried out, bidder 1 incurs a low cost of production, $\widetilde{c_l}$, while bidder 2 bears a high cost, $\widetilde{c_h}$, whereas the dominance is reversed if the project specification happens to be A'. For instance, one may think of a large and a small firm. The former has higher fixed costs but can take advantage of economies of scale, whereas the latter has higher variable costs, but negligible fixed costs. If A and A' differ with respect to the size of the project, it is conceivable that the large firm will bear a lower total cost of production than the small firm when the bigger design is undertaken and vice versa.

Firms' production costs $\widetilde{c_l}$ and $\widetilde{c_h}$ are distributed independently over the intervals $[\underline{c_l}, \overline{c_l}]$ and $[\underline{c_h}, \overline{c_h}]$, respectively, with $\underline{c_l} < \overline{c_l} \leq \underline{c_h} < \overline{c_h} < v$.

In light of these cost parameters, it is plain that if the buyer holds an auction for project A and this subsequently turns out to be flawed, then a type-1 bidder will be somewhat reluctant to shift to project A' as it involves a higher cost of production while a type-2 bidder will eagerly accept the change as it will allow him to substantially cut the production cost. Such a feature clearly alters the renegotiation claims of the two bidders and under some circumstances can even prevent a design change from occurring. In turn, these considerations undoubtedly affect the bidding strategies pursued by the two firms.

Thus, the timing of the game works as follows:

- At time 0, β is observed by the potential contractors and by the buyer. The latter decides which project to auction off, between A and A', and chooses the auction format.
- At time 1, the auction takes place and the contract is granted to either firm 1 or 2.
- At time 2, the uncertainty is realized. If the project design chosen at time 0 exhibits pitfalls, a renegotiation between the buyer and the selected contractor occurs and, if successful, there is a design change.

Throughout, we focus on fixed-price contracts where the awardee does not receive any reimbursement for the costs he incurs. We make this choice for several reasons. In the first place, in our setting agents are risk-neutral and, as a result, the parties do not have to turn to an incentive contract where a fraction of the costs of production is borne by the buyer to strike the optimal risk-sharing agreement[4]. Furthermore, fixed price contracts are most often awarded by auctions: specifically, the Federal Acquisition Regulations (FAR) in the United States urge the use of auctions of fixed price-contracts for public sector purchases (see Bajari et al., 2008). Last but not least, Bajari and Tadelis (2001) have emphasized the merits of a cost-plus contract when it comes to renegotiating an agreement, and their argument is mainly based on their greater flexibility to adapt to ex-post adjustments of original agreements than fixed-price contracts. Here, we wonder whether the award of fixed-price contract may prove a wise decision by the buyer in presence of a known positive probability that the initial agreement will warrant some changes.

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[4]Following McAfee and McMillan (1986), the optimal linear contract takes on a fixed-price format if agents are risk-neutral. Here we ignore what they label as the competitive-bidding effect

3 The Renegotiation Game

Now, to formally determine the utility function of the buyer and the profit functions of the two bidders, we need to make an assumption on the way the renegotiation takes place ex-post. We assume that the cost parameters of the awardee are unobservable. In other words, if a design change is required by the buyer not to incur the net loss of welfare h, the cost parameters of the contractors still remain private information and do not enter directly into the renegotiation requests of the parties. This assumption is consistent with the idea spelled out by Bajari and Tadelis that only the total production costs may be verifiable while modification costs may not. This element nears this model to the Laffont and Tirole's approach to procurement and renegotiation, in contrast to the Baron and Myerson's perspective where the regulator is unable to observe firm's cost[5]. Since the extent to which the design change has hurt the cost efficiency of the contractor cannot be verified, at the renegotiation stage the agent cannot claim any reimbursement for the increased cost of delivery the good. Nonetheless, he can still refuse to approve any revision of the original agreement.

In addition, in the next section we rest on the assumption that the procurer is able to identify the type of the firm he deals with at the renegotiation stage. This is consistent with the idea that the two firms differ with respect to exogenous characteristics which can be observed by the buyer, such as their size.

In light of the above, we need to work out a bargaining model in presence of asymmetric information. One comfortable option is to focus on two polar cases, as Bajari and Tadelis do in their 2001 paper, namely, when either party to the contract makes a take-it-or-leave-it offer on which he can wholly commit. This is also consistent with the results of the literature on bargaining under asymmetric information (Samuelson, 1984) which predicts that the parties may sometimes fail to reach an agreement and that the first best is attainable provided that either party may stand by the first-and-final offer he makes.

To begin with, we take into consideration a setting where it is the awardee who can make the take-it-or-leave-it offer at the renegotiation stage. Then, we will focus on the case where it is the buyer to make the first-and-final offer.

4 The contractor makes the first-and-final offer

Clearly, if the firm who has been granted the contract happens to be involved in a renegotiation with the procurer, he will make the most of his perfect information about the buyer's utility, asking for h, which is publicly observable. However, in some occurrences the contractor may be still unwilling to accept the design change: this event occurs when the awardee has to incur a higher cost of production to deliver the new project design and the hold-up rent, h, is not large enough to reimburse him for the increased cost. Therefore, we need to take into account the probability that the renegotiation breaks down when an auction for A (A') has been held, 1 (2) has been awarded the contract and the procurer requests a design change.

It is thus necessary to determine under which conditions a profitable renegotiation occurs when the proposed design change entails a higher cost of production for the awardee. To do so, denote by $\widetilde{c}$ the random variable $\widetilde{c_h} - \widetilde{c_l}$, whose distribution and density are $F(\widetilde{c})$ and $f(\widetilde{c})$, respectively[6].

[5] See, for instance, Laffont and Tirole (1986) as compared with Baron and Myerson (1982).

[6] $f(\widetilde{c})$ is the convolution of the density functions of $\widetilde{c_h}$ and of $\widetilde{c_l}$.

Consequently, when the buyer auctions off project design A and, then, he is willing to adopt the alternative design, there is a probability equal to $1-F(h)$ that the higher cost of production firm 1 has to incur hinders the renegotiation process. Since both h and their own cost parameters are known to the bidders before taking part in the tender process, we need to distinguish between the two cases.

4.1 Renegotiation is always successful

It is worthwhile starting with a setting where the parties always succeed in renegotiating the contract, irrespective of the identity of the winning bidder. This occurrence happens with probability $F(h)$.

The buyer's expected utility when he initially avails himself with project design A is given by:

$$EU(A) = v - b_a - \beta h \tag{1}$$

where the subscript a can be equal to either 1 or 2 and denotes the awardee.

Instead, bidders' profit functions take on the following forms:

$$\begin{cases} E\pi_1(A) = [b_1 - (1-\beta)\widetilde{c_l} - \beta(\widetilde{c_h} - h)]Pr(b_1 < b_2) \\ E\pi_2(A) = [b_2 - (1-\beta)\widetilde{c_h} - \beta(\widetilde{c_l} - h)]Pr(b_2 < b_1) \end{cases}$$

It is important to characterize the bidders' types which consist of two components: the expected cost of production (which we label c_{iA}) and the expected rent whose main impact is to shift to the left the expected total cost of delivering the good.

$$\begin{cases} \theta_{1A} = \overbrace{(1-\beta)\widetilde{c_l} + \beta\widetilde{c_h}}^{c_{1A}} - \beta h \\ \theta_{2A} = \underbrace{(1-\beta)\widetilde{c_h} + \beta\widetilde{c_l}}_{c_{2A}} - \beta h \end{cases}$$

It is also helpful to determine the interval on which the bidders' types are defined:

$$\begin{cases} \theta_{1A} \sim \Phi_1[(1-\beta)\underline{c_l} + \beta\underline{c_h} - \beta h; (1-\beta)\overline{c_l} + \beta\overline{c_h} - \beta h] = \Phi_1[\underline{\theta_{1A}}; \overline{\theta_{1A}}] \\ \theta_{2A} \sim \Phi_2[(1-\beta)\underline{c_h} + \beta\underline{c_l} - \beta h; (1-\beta)\overline{c_h} + \beta\overline{c_l} - \beta h] = \Phi_2[\underline{\theta_{2A}}; \overline{\theta_{2A}}] \end{cases}$$

As a matter of fact, what characterizes the bidders is only the cost function while the rent they expect to earn is the same. The profit functions we have set out above are correct as long as h is greater than the actual cost of modifying the design of the project, c, so that the renegotiation between the buyer and the contractor always proves successful. In particular, the parties to the contract succeed in renegotiating the contract even if the awardee for project designs A and A' are firms 1 and 2, respectively.

Before presenting our first result, we introduce this following lemma concerning the bidding behavior of the agents. If bidders' cost parameters are drawn independently and their expected profit functions are both monotonically decreasing in the firms' types and are weakly supermodular (note that both conditions are fulfilled by the profit functions depicted above and the latter is always met when bidders are risk neutral), the following lemma holds.

Lemma 1. *The bidders bid accordingly to a weakly monotonic bidding function. That is, if* $b_i = B_i(\theta_i)$, *then* $B_i'(\theta_i) \geq 0$ *for any* $\theta_i \in \Phi_i$, *for* $i = 1, 2$.

The proof can be found in the appendix.

Proposition 1. *If it holds that (i) the contractor is entitled to make, and can commit to, a take-it-or-leave it offer to the buyer at the renegotiation stage; (ii) if the conditions of lemma 1 are fulfilled; (iii) $h \geq c$, then:*

1. ***Competitive bidding mechanisms such as a First Price Auction and a Second Price Auction achieve ex-ante allocative efficiency**. The bidder whose expected cost of production of the project is the lowest will win the auction. Since the rent the bidders expect to enjoy is the same, the only distinguishing feature between the two bidders is their cost parameters. If there is little uncertainty about which project design will eventually be undertaken, that is, if β is either sufficiently low or sufficiently high, a First Price Auction (FPA) proves weakly superior to a Second Price Auction (SPA): the lack of uncertainty about the project design strengthens the asymmetry between the two bidders and can give rise to a distribution shift which, as Maskin and Riley (2000, proposition 4.3) show, induces the buyer to favor a FPA mechanism.*

2. ***The hold-up rent h is not a concern for the buyer**. Indeed, it is entirely discounted at the bidding stage and the reason is straightforward: both bidders are aware of the probability with which they will earn a rent, if they are granted the project, and they know the magnitude of the rent itself. A competitive bidding process will allow the buyer to extract all the winner bidder's willingness to pay to be granted the right to potentially earn the hold-up rent, that is, βh. This result is consistent with the rent-seeking literature[7].*

The following corollary stems from the above proposition:

Corollary 1. ***Irrelevance of the project design at the auction stage.** If the assumptions of proposition 1 are fulfilled, then it does not matter which project design is auctioned off as the contract is always awarded to the firm who is most efficient ex-ante and the hold-up rent is entirely discounted at the bidding stage.*

4.2 Renegotiation may fail to occur

Now, we turn to the case where the hold-up rent is lower then the increased cost of production that a design change requires and which occurs with probability $(1-F(h))$. The buyer's expected utility is always defined by equation 1, as the probability that the renegotiation breaks down does not affect his utility when he has no bargaining power.
What changes is the expected profit function of bidder 1 when project A is auctioned off:

$$\begin{cases} E\pi_1(A) = [b_1 - \widetilde{c_l}]Pr(b_1 < b_2) \\ E\pi_2(A) = [b_2 - (1-\beta)\widetilde{c_h} - \beta(\widetilde{c_l} - h)]Pr(b_2 < b_1) \end{cases}$$

Since a renegotiation cannot occur when 1 has won the tender process, the buyer and the contractor will be stuck to project design A. As a consequence, the distribution of bidder 1's

[7]Furthermore, consider that the buyer should set a ceiling to the bids he receives and turns down all the bids above $v - \beta h$, as they do not meet his participation constraint. In addition, note that if the bidders bid accordingly to a monotonic bid function the minimum observable bid is given by $\underline{\theta_{iA}}$ and, as a result, they always subtract βh from their true cost parameter, c_{iA}.

type takes on the following form:

$$\theta_{1A} \sim \Phi_1[\underline{c_l}; \overline{c_l}]$$

Unlike that of bidder 2, bidder 1's type is affected neither by h nor by β. Adapting the Maskin and Riley's framework to a procurement auction, I can define the weak bidder (w) as the one whose type's distribution first order stochastically dominates that of the strong bidder (s):

$$\Phi_w(\theta) < \Phi_s(\theta), \forall \theta \in (\underline{\theta_s}, \overline{\theta_w}) \tag{2}$$

Since - when A is the initial project design - the distribution of bidder 2's type varies with the value of β and h, the identities of the strong and weak bidders are endogenously determined by these parameters. Even though the buyer cannot set either of them, he can decide which project design to auction at the beginning of the game (whether A or A'), thereby affecting the probability of a renegotiation and, in turn, the distribution of the type of the bidder willing to renegotiate the contract (2 and 1, respectively). In other words, the buyer can influence the competitiveness of the bidding process with his initial decision of the project design. To draw some conclusions on the buyer's optimal strategy, we need to recall the definition of Conditional Stochastic Dominance.
First, consider that (2) implies

$$\underline{\theta_s} \leq \underline{\theta_w} \quad \text{and } \overline{\theta_s} \leq \overline{\theta_w}$$

Then, define Conditional Stochastic Dominance (CSD) as follows:

Definition 1. *Conditional Stochastic Dominance is fulfilled if the ratio* $\frac{\Phi_w(\theta)}{\Phi_s(\theta)}$ *is increasing on the interval* $[\underline{\theta_w}; \overline{\theta_w}]$. *Formally,*

$$\forall x \in [\underline{\theta_w}; \overline{\theta_w}], \quad \textit{it must hold that } \frac{\partial}{\partial x}[\frac{\Phi_w(x)}{\Phi_s(x)}] > 0$$

One consequence of assuming CSD is that the distribution of the equilibrium bids of the weak firm first order stochastically dominates that of the strong firm, provided that the bids are weakly monotonic in the bidders' types.
Before applying the other insights stemming from the analysis of Maskin and Riley (2000) to the current setting, where the buyer's problem, after having observed the value of β is that of choosing which project design to auction off, we need to introduce the following definition:

Definition 2 (Wrong project)**.** *A wrong project is a project design whose prior probability of being flawed exceeds that of another design specification available to the buyer.*

Note that in this model where only two alternative designs are available, the wrong project is the one which has the higher probability of exhibiting pitfalls. We can now present our second result:

Proposition 2. ***Auction of the wrong project.*** *If it holds that (i) the contractor is entitled to make, and can commit to, a take-it-or-leave it offer to the buyer at the renegotiation stage; (ii) if the conditions of lemma 1 are fulfilled; (iii) if $h \leq h^* \leq c$, where h^* is a decreasing (increasing) function of β when A (A') is the starting project; (iv) conditional stochastic dominance is fulfilled, then:*
If β is higher (lower) than $\frac{1}{2}$, the buyer finds it profitable to auction off the project A (A'), namely the project specification more likely to be flawed ex-post so as to stiffen competition at the bidding stage and take advantage of more aggressive bids.

To understand this result, focus on the auction of the project specification A. When β is very low, there exists a strong asymmetry between the distribution of the two bidders' types and bidder 1, who is the strong bidder, can win the auction by submitting a very high bid which is detrimental to the buyer. However, as β grows large, the distribution of 2's type gets closer to that of 1 and from a certain point on the identity of the strong and the weak bidder will change. From the buyer's standpoint what is relevant is that as β increases he receives lower bids and, as a result, the expected transfer he has to pay to the awardee decreases[8] . This competition effect is partially offset by the higher expected loss of utility the buyer has to incur, βh. Therefore, for any value that β can take on the interval $(\frac{1}{2}; 1)$, it is possible to pinpoint a threshold value, h^*, above which the benefits of increased competition are outweighed by an excessive expected rent. The function h^* is decreasing in β, when A is the starting design, because the buyer feels the benefits of competition when the bidders' types' distributions are more homogeneous[9]. Then, if β approaches unity, bidder 2 and bidder 1 already have similar expected cost of production and a too high hold-up rent may overly favor bidder 2. The implication is that if the assumptions of proposition 2 are satisfied the buyer is better off when he auctions off project design A when $\beta > \frac{1}{2}$ and design A' when $\beta < \frac{1}{2}$.

5 The buyer makes the first-and-final offer

We can now proceed to the second scenario, where it is the buyer who is entitled to make the take-it-or-leave-it offer. Here, when it comes to renegotiating the original agreement the picture becomes more cumbersome. Again, let us focus on the case in which the project specification initially chosen is A. On the one hand, when faced with a type-1 firm, the buyer is willing to persuade him to accept the design change and thereby he is poised to give up some fraction of the renegotiation gain that accrues to himself. On the other hand, when confronted with a type-2 contractor, the buyer wishes to seize some fraction of the design change gain that accrues to the firm. This feature gives rise to two consequences:

a) Irrespective of whom has won the auction, there exists some positive probability that the renegotiation breaks down and the parties remain stuck to the initial agreement which requires A be delivered by the winning bidder.

b) When the buyer has bargaining power, his expected utility at the renegotiation stage depends on whom has been granted the contract. Therefore, as we show below, it is not optimal for the buyer to hold a "low-price auction" to assign the project.

To start with, consider the take-it-or-leave it offer that the buyer will make to a type-1 firm at the renegotiation stage. The buyer will rationally make an offer which maximizes his own ex-post payoff, knowing that the firm will turn down any offer which does not make up for the higher cost of production he has to incur to deliver A' instead of A. Thus, the buyer will make the seller an offer ω which, with probability $F(\omega)$, will prove successful. The offer ω will be

[8]This intuition is triggered by Maskin and Riley (2000): if a weak bidder faces a strong bidder rather than another weak he will react by submitting a more aggressive bid. By the same token, a strong bidder who faces an increasingly (as β rises) less weak bidder will respond by bidding more aggressively.

[9]Conversely, if the buyer initially avails himself with project specificationA', h^* in increasing in β in the interval $(0, \frac{1}{2})$.

chosen so as to minimize the renegotiation loss:

$$F(\omega)\omega + (1 - F(\omega))h$$

that is:

$$\omega^* = h - \frac{F(\omega^*)}{f(\omega^*)} \in [0, h] \tag{3}$$

If $\frac{F(\omega^*)}{f(\omega^*)}$ is increasing in ω, then (3) has a unique, interior solution[10].

Faced with a type-2 operator, the buyer will submit a different take-it-or-leave-it offer, ν, seeking to grab the highest possible share of the renegotiation gain which accrues to the contractor, without compromising the renegotiation itself. Here, with probability $F(\nu)$ the renegotiation breaks down. The buyer will choose the offer so as to maximize the following expression:

$$(1 - F(\nu))\nu - F(\nu)h$$

Thus, the optimal offer is[11]:

$$\nu^* = \frac{1 - F(\nu^*)}{f(\nu^*)} - h \geq 0 \tag{4}$$

We denote by $\eta_1(\beta)$ the probability that 1 wins the contract and we write the profit functions as follows:

$$\begin{cases} E\pi_1(A) = [b_1 - (1-\beta)\widetilde{c_l} - \beta[F(\omega^*)(\widetilde{c_h} - \omega^*) + (1 - F(\omega^*))\widetilde{c_l}]\eta_1(\beta) \\ E\pi_2(A) = [b_2 - (1-\beta)\widetilde{c_h} - \beta[F(\nu^*)\widetilde{c_h} + (1 - F(\nu^*))(\widetilde{c_l} + \nu^*)](1 - \eta_1(\beta)) \end{cases}$$

The utility the buyer can attain at the renegotiation stage depends on the identity of the firm who has been granted the contract:

$$EU(A) = v - \eta_1(\beta)\overbrace{[b_1 + \beta(F(\omega^*)\omega^* + (1 - F(\omega^*))h)]}^{T_1} - (1 - \eta_1(\beta))\overbrace{[b_2 + \beta(F(\nu^*)h - (1 - F(\nu^*))\nu^*)]}^{T_2}$$

Where T_1 and T_2 are the expected total cost of awarding the contract to bidders 1 and 2, respectively.

When the buyer auctions off a design project (say A), he must not consider the price as the only relevant variable in the allocation rule, for two different reasons: first, the firm specialized in delivering the starting project would have a huge advantage over his opponent, in so harming competition; second, were the buyer to receive the same offer from the two bidders, he would much rather grant the project to the less specialized firm. This second claim is due to the observation that the principal always prefers to renegotiate with the party from whom he can elicit the highest utility, i.e., the most willing to shift to the alternative design specification. As a consequence, the allocation rule at the auction stage should be:

$$\eta_1(\beta) = \begin{cases} 1, & \text{if } T_1 \leq T_2 \\ 0, & \text{otherwise} \end{cases}$$

How will the buyer behave at the first stage in face of these allocation and transfer rules? We can distinguish between two cases which depend on the distribution of the cost differential, F,

[10] Note that this condition is satisfied for any log-concave distribution. Since $f(\widetilde{c})$ is obtained as the convolution of the density functions of $\widetilde{c_h}$ and of $\widetilde{c_l}$ and convolution is an operation that preserves log-concavity, what is ultimately required is that the densities of $\widetilde{c_h}$ and of $\widetilde{c_l}$ are log-concave (such as uniform).

[11] Note that $\frac{1-F(\nu)}{f(\nu)}$ is decreasing in ν for any log-concave distribution.

and on the value of the hold-up rent, h. If f is log-concave so that $\frac{F(x)}{f(x)}$ and $\frac{1-F(x)}{f(x)}$ are increasing and decreasing in x, respectively, then[12]:

Claim 1. *Whenever h is considerably higher than the expected value of $\widetilde{c}$, the buyer ought to hold an auction for the right project.*

Indeed, if h is particularly large, the buyer strives to avoid failing to renegotiate the agreement and, thereby, he will ask for a ν^* very close to zero when dealing with a type-2 firm, whereas he will submit a very generous offer to a type-1 firm. As a consequence, renegotiating with bidder 1 will turn out to be very costly and a large handicap will be put in place. If $\beta > \frac{1}{2}$, 2 is highly likely to win the auction by offering a very high bid. Hence, the buyer will be better off holding an auction for the right project. In other words, the buyer will tend to minimize the probability that the contract will be reviewed.

Claim 2. *If h is small compared to the expected value of $\widetilde{c}$, the buyer should optimally auction off* ***the wrong project****.*

In this case, the buyer will attempt to grab a fraction of the cost saving when he is faced with a type-2 bidder. Instead, with a type-1 bidder, he may end up not renegotiating the contract, since the reimbursement will likely exceed the loss he would experience by sticking to the original project design. Thus, holding an auction for the wrong project again becomes a device to stiffen competition at the bidding stage. In addition, if the less suitable contractor for the initial project is hired, the buyer may enjoy a significant gain should the renegotiation take place.

In summary, we attain the same counterintuitive result as in section 4 when it is the buyer to be entitled to make a first-and-final offer at the renegotiation stage, provided that the value of the hold-up rent does not dominate the differential cost of providing different design specifications of the project.

6 Conclusion

Renegotiation of procurement contracts seems to be a widespread practice. Furthermore, in a number of cases, renegotiation is apparently unrelated to any *contract incompleteness* explanations, namely, it is not the emergence of ex-ante unforeseeable contingencies to trigger substantial contract modifications.

In this paper, we have shown that if the prior probability of a partial default of a project specification is known to all the parties to a contract, the buyer may act strategically when choosing the design of the project to auction. In particular, the buyer may decide to hold an auction for the project design which has a lower probability of being appropriate, in an effort to enhance competition at the bidding stage or to seize a fraction of the renegotiation gain (i.e., the reduced cost) which accrues to some contractors.

[12] Notice that the results are again shown taking on the perspective of a buyer who starts with the project specification A, for which firm 1 has a cost advantage over firm 2.

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Appendix

Lemma 1. *The bidders bid accordingly to a weakly monotonic bidding function. That is, if* $b_i = B_i(\theta_i)$*, then* $B_i'(\theta_i) \geq 0$ *for any* $\theta_i \in \Phi_i$*, for* $i = 1, 2$*.*

Proof of Lemma 1. The assumptions required to prove this lemma are the following:

(a) Bidders' types are drawn independently. Formally[13]:

$$\begin{cases} \phi_i(\theta_i|\theta_j) = \phi_i(\theta_i) \\ \phi_j(\theta_j|\theta_i) = \phi_j(\theta_j) \end{cases}$$

(b) Bidders' expected profits must decrease monotonically in their own types: $\frac{\partial \pi_i}{\partial \theta_i} < 0$ for $i = 1, 2$.

(c) Firms' expected profits must be weakly supermodular: $\frac{\partial^2 \pi_i}{\partial b \partial \theta_i} \geq 0$ for $i = 1, 2$.

In our model, the expected profit function of bidder i takes on the following form:

$$E_{\theta_j} \pi_i(b_i, \theta_i) = (b_i - \theta_i) Pr(b_i < B_j(\theta_j))$$

[13]Bear in mind that the generic bidder's type, θ_i, is drawn from a distribution Φ_i, with density ϕ_i, on the interval $[\underline{\theta_i}, \overline{\theta_i}]$.

where $B_j(\theta_j)$ is firm j's bid function which solely depends on his type. We can define $p_i(b_i)$ as the conditional probability of i's winning the procurement auction with a bid equal to b_i. Formally:

$$p_i(b_i) = \int_{Pr(b_i < B_j(\theta_j))} \phi_j(\theta_j) d\theta_j$$

which is a weakly decreasing function of b_i, because of assumption (c).
Now, suppose that $\widetilde{b_i}$ and b_i' are the best response of player i when his type are $\widetilde{\theta_i}$ and θ_i', respectively. If so, for any $\widetilde{b_i}$ and b_i' it must hold that:

$$E_{\theta_j}\pi_i(\widetilde{b_i}, \widetilde{\theta_i}) = (\widetilde{b_i} - \widetilde{\theta_i})p_i(\widetilde{b_i}) \geq (b_i' - \widetilde{\theta_i})p_i(b_i') \tag{5}$$

by definition of best response. Note that the right-hand side of (1) can be written as:

$$b_i'p_i(b_i') - \theta_i'p_i(b_i') + \theta_i'p_i(b_i') - \widetilde{\theta_i}p_i(b_i') = (b_i' - \theta_i')p_i(b_i') + (\theta_i' - \widetilde{\theta_i})p_i(b_i')$$

Therefore, (5) can be rewritten as

$$E_{\theta_j}\pi_i(\widetilde{b_i}, \widetilde{\theta_i}) \geq E_{\theta_j}\pi_i(b_i', \theta_i') + (\theta_i' - \widetilde{\theta_i})p_i(b_i') \tag{6}$$

And, if $\theta_i' > \widetilde{\theta_i}$, we attain that:

$$p_i(\widetilde{b_i}) \geq \frac{E_{\theta_j}\pi_i(\widetilde{b_i}, \widetilde{\theta_i}) - E_{\theta_j}\pi_i(b_i', \theta_i')}{\theta_i' - \widetilde{\theta_i}} \geq p_i(b_i') \tag{7}$$

as the numerator is always positive due to assumption (b). Furthermore, if we let $\theta_i' \to \widetilde{\theta_i}$ we have that

$$\frac{\partial E_{\theta_j}\pi_i(b_i, \theta_i)}{\partial \theta_i} = -p_i(b_i)$$

Since the probability that i wins the auction when his type rises does not increase and the fact that the function p_i in weakly decreasing in b_i it cannot be that $\theta_i' > \widetilde{\theta_i}$ and $b_i' < \widetilde{b_i}$.

$\square$