Time Overruns as Opportunistic Behavior in Public Procurement*

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Abstract

We consider the supplier's strategic choice on delivery time in a public procurement setting as the result of the firm's opportunistic behavior on the optimal investment timing when production costs are uncertain. We model the supplier's trade-off between the option value to defer and the penalty payment in the event of delays. We also take into account the issue of penalty enforcement, which in turn depends on both the discretion of the court of law in voiding contractual clauses (i.e. the penalties for delays) and the "efficiency" of the judicial system (i.e. the length of civil trials). We test our main results on Italian public procurement data showing that the supplier's incentive to delay is greater the higher the volatility of production costs and the lower the "efficiency" of the judicial system. We then calibrate the model using parameters that mimic the Italian scenario on public works procurement and calculate the maximum amount that a supplier is "willing to pay" (per day) to postpone the delivery date and infringe the contract provisions. Our calibration results are consistent with the theoretical model's predictions and the empirical findings.

KEYWORDS: STRATEGIC TIME OVERRUNS, PUBLIC PROCUREMENT, REAL OPTIONS

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1 Introduction

Public procurement is a versatile mechanism that can efficiently convey public resources to private operators, but its benefits can rapidly be erased by the adverse outcomes that usually derive from uncertainty over the production costs. The economic and engineering literature place a different emphasis on the effects that this uncertainty might have on procurement. Most economic analysis on this topic focuses on the information asymmetry of production costs between the supplier and the buyer (Laffont and Tirole, 1993) considered by the latter as the main source of inefficiency in contracting. Differently, engineering and construction management literature tends to concentrate on the volatility of the production costs and its effects on the supplier's pricing strategy (Crowley and Hancher, 1995; Levin 1998; Xu and Tiong, 2001). In particular, uncertainty on estimated investment costs determines significant risks and opportunities which may induce suppliers to strategically adopt opportunistic behaviors, such as under-pricing and time overruns (King and Mercer, 1985; Chapman et al. 2000; You and Tam, 2006; Lo, Lin and Yan, 2007). The seminal paper by Bajari and Tadelis (2001) - modelling the tension between ex-ante incentives and ex-post transaction costs due to costly contract renegotiation – represents a first connection between these literatures in procurement, shedding light on ex-post adaptation and ex-ante screening in procurement.[1]

To prevent the occurence of strategic time overruns, public buyers usually include a penalty clause for delays in Public Procurement Contracts (PPCs), where the amount of compensation due for delays is specified. Whether or not such a penalty has a role in limiting the supplier's opportunistic behaviour typically depends on the committed fee and its enforcement by the court of law to which the parties refer to settle any disputes.

In this paper we investigate in a public procurement setting whether the perceived uncertainty over construction costs generates an incentive for the supplier to adopt an opportunistic behavior in the form of time overruns. Specifically we derive the value of a PPC that includes an option-value to wait for ongoing information about construction costs less the value of the penalty expected to be paid in the event of delay. We also address the issue of penalty enforcement by including in our model both the discretion of the court of law in enforcing contractual clauses (i.e. the penalty for delays) and the "efficiency" of the judicial system (i.e. the length of court trials).

Our model shows, first, that the higher the variance of production costs, the stronger the incentive to delay; second, that the incentive to delay is magnified in setting where the public buyer, i.e. the Contracting Authority (CA), has little

[1] Recently, in the same vein, Lewis and Bajari (2011) provided empirical evidence that, when time is an issue, awarding highway procurement contracts through an auction design, scoring the supplier's bid on costs to execute the contract along with the supplier's project completion time is more efficient than awarding through an auction where participants bid exclusively on price.

or no chance of seeing the committed penalties enforced because the "efficiency" of the judicial system is low and/or the court of law has considerable discretion.

Committed penalties for delay may consequently not represent significant losses to the defaulting party because the implementation of any trial is too slow or weak, or because the penalty to be paid is small by comparison with the supplier's option value to delay the works.

We then test our theoretical results on the database compiled by the Italian Authority responsible for controlling and monitoring PPCs (AVCP)[2] obtaining empirical findings consistent with the predictions of our model. Finally, we calibrate the model using parameters that mimic the Italian scenario for PPCs and calculate the maximum amount that a supplier is "willing to pay" (per day) to postpone the delivery date.

To the best of our knowledge, the model described here is the first to investigate time overruns in a procurement setting as the result of the supplier's opportunistic behavior on the optimal investment timing, when penalties for delay are included in the contract. Our model combines irreversible investment under uncertainty with strategic timing in executing procurement contracts, and it mainly contributes to two strands of literature. First, we complement the existing literature on optimal investment timing (Dixit Pindyck, 1994; Trigeorgis, 1996) with a novel application in a procurement setting, providing a new investigation of the supplier's strategic choice on the contract delivery time.

Application of the real option approach to the modeling of opportunistic behavior in delaying the execution of contracts was first discussed in Tufano and Moel (2000) and more recently by Monteiro da Silva Fenolio and Accioly Fonseca Minardi (2009), Bastian-Pinto *et al.* (2012) and Dosi and Moretto (2012).

Second, our model contributes to the literature on judicial contractual enforcement, providing a theoretical framework in which the discretion of the court in voiding contractual clauses and the "efficiency" of the judicial system matter (Dimitri *et al.*, 2006; Guash *et al.*, 2006; Anderlini *et al.*, 2007). In particular Eggleston *et al.* (2000) highlighted that the enforcement of contractual clauses can be limited when the cognizant law court has discretion in reducing (or even not enforcing) the penalties. Recent analyses investigating judicial contractual enforcement in Italy showed important effects of local court "efficiency" on the credit market (Jappelli *et al.*, 2005) and the performance of public contracts (Coviello *et al.*, 2011).

This paper is organized as follows. In Section 2, we model the value of a PPC that includes the option-value to delay the works. In Section 3, we present empirical evidence on the determinants of time overruns in Italian PPCs. Then, in Section 4 we calibrate our model using parameters that mimic the Italian scenario for PPCs to determine the option value to defer. In Section 5 the conclusions are discussed.

[2] Autorità di Vigilanza sui Contratti Pubblici di Lavori Servizi e Forniture (AVCP).

2 Strategic time overruns

In a Public Procurement setting, the supplier's opportunistic behavior in the form of time overruns can be interpreted as a strategic choice. In executing a contract, i.e. in making an irreversible investment, when production costs are uncertain, suppliers may find it optimal to delay the delivery of the works in the hope of getting higher payoffs in the future. Such flexibility in delivering the contracted works, if optimally exercised, represents an additional value for the supplier. In order to contrast suppliers' time overruns, the buyer usually includes a penalty for delays in the contract. In fact when considering the trade-off between timely and delayed contract execution, the supplier will take into account the penalty to be paid in the event of delay and its potential enforcement by the court of law.

Our analysis is based on two arguments. Firstly a correlation exists between the volatility of construction costs and the supplier's option value to wait for more information about cost evolution before committing to an irreversible decision. Secondly, specifically referring to the Italian scenario, the enforceability of the penalty is not straightforward. While, on the one hand, Italian legislation establishes that the CA has the right to commit the supplier to pay a penalty in the event of delays, on the other hand, the supplier may oppose payment of the penalty when the amount involved is perceived as "manifestly excessive" (i.e. the penalty fee is not proportional to the "damage" caused by the delay in the delivery of the works) or she claims not to be fully responsible for the delays and thus takes the matter to court.

2.1 The model

Let's consider the case of a CA awarding a fixed-price PPC to a supplier, paying an amount p; with no loss of generality, we normalize this amount to $p = 1$. The PPC involves building a public infrastructure of specified dimensions with exogenous technical characteristics defined ex-ante. Further, to economize on notation, we assume that the contract delivery time, i.e. the maximum time allowed for completion of all the works (Hersbam *et al.*, 1995), which is defined prior to awarding of the contract, is set to zero.[3] Finally, the contract includes the supplier's liability for completion on time: that is in the event of any delays, the supplier is liable to pay a penalty, c, for each day of delay established as

[3] The contract time, starting from when the contract is awarded, can be either specified by the project engineers (Lewis and Bajari, 2011, p. 1177), or chosen by the CA aiming at maximizing the total expected welfare function which should account for the gross total value of the project minus the cost of delays (i.e. the value of the project for the taxpayers). In the latter case, without any loss in generality, we can assume that the total value of the project is sufficiently high, so that it is always in the interest of the CA to have the infrastructure as soon as possible.

a percentage of the contract price.[4] Under these assumptions, the Net Present Value (NPV) at time t, F_t, of the supplier that complies with the contract delivery time is given by:[5]

$$F_t = 1 - C_t \ , \tag{1}$$

where C_t are the production costs.

If the production costs are stochastic, however, their variability makes it *de facto* valuable for the supplier to wait and delay completion of the works. This investment timing flexibility has a value that should be added to the project's NPV as expressed in (1). In particular, we assume that the construction costs C_t evolve over time with a Geometric Brownian Motion:[6]

$$dC_t = \alpha C_t dt + \sigma C_t dz_t \ , \tag{2}$$

where $\alpha > 0$ is the drift and $\sigma > 0$ is the volatility.[7] Then, the supplier's opportunity to defer the execution time becomes analogous to a Put Option. Since the supplier cannot fully anticipate the costs and assuming, for the sake of analytical tractability, that she hold a perpetual option, the value of the awarded contract is given by:[8]

$$P_t = E_t \left\{ e^{-r(\tau - t)} F_\tau - \pi \int_t^\tau c e^{-r(s-t)} ds \right\} \tag{3}$$

where $E_0(.)$ is the expectation taken at time t with respect to (2). In (3) the first term $e^{-r(\tau-t)}F_\tau$ is the discounted net benefit obtainable by investing at

[4] We do not consider the case where the supplier is awarded a premium (incentive) if she delivers the work before the deadline in the contract; this case is scarcely significant in Italy where incentives are very seldom introduced in PPCs due to very stringent budget constraints.

[5] Setting the contract time to zero implicitly assumes that the works can be built instantaneously. This assumption can be relaxed without substantially altering the results. Let's assume that it takes a given "time-to-build" the works but there is a maximum rate, m, at which the supplier can invest in every period (year). Denoting the total expenditure as C_t, it takes $T = C_t/m$ periods (years) to complete the project. Assuming that expenditures are made continuously over T, their present value is:

$$\hat{C}_t = \int_0^{C_t/m} m e^{-rs} ds = (1 - e^{-rC_t/m}) \frac{m}{r}$$

Since $e^{-rC_t/m} \simeq 1 - r\frac{C_t}{m} + ...$, however, we shall have $\hat{C}_t \simeq C_t$ and the analysis can proceed more or less as in the text.

[6] In (2), dz_t is the increment of a standard Brownian process with mean zero and variance dt (Dixit and Pindyck, 1994).

[7] Assuming that the state variable follows a Geometrical Brownian Motion is standard in real-option models. However, alternative processes, such as mean-reverting, can be used. This would complicate the analysis, without changing the results significantly.

[8] This assumption, which allows us to find closed-form solutions, is rather unrealistic, since the CA is generally entitled to terminate the contract when delays become "unacceptably long". For example, Italian law caps the maximum amount of the penalty to be paid by the supplier at 10% of p (see art. 145 Presidential Decree no. 270/2010). If the delays incur a penalty exceeding this threshold, the CA can terminate the contract and award the works to another supplier. In this case (3) becomes an American Put Option, with a maturity time T given by: $\int_0^T ce^{-rs}ds = 10\%p$. Modeling this option is more complicated than (3), but none of the results presented in this section are substantially affected.

costs $C_\tau < C_t$; $\int_t^\tau ce^{-r(s-t)}ds$ is the value of the penalty fee; $\pi \in [0,1]$ is the probability of the supplier paying this penalty; r is the discount rate and τ is the supplier's optimal delivery time.

By the law of iterated expectations, the supplier problem consists of choosing the stopping time $\tau \geq t$ that maximizes:[9]

$$\begin{aligned} P_t &= E_t(e^{-r(\tau-t)})\left(F_\tau + \pi\frac{c}{r}\right) - \pi\frac{c}{r}. \\ &= \left(\frac{F_t - 1}{F_\tau - 1}\right)^\beta \left(F_\tau + \pi\frac{c}{r}\right) - \pi\frac{c}{r} \end{aligned} \tag{4}$$

where:

$$\beta = (\frac{1}{2} - \frac{\alpha}{\sigma^2}) - \sqrt{(\frac{1}{2} - \frac{\alpha}{\sigma^2})^2 + \frac{2r}{\sigma^2}} < 0$$

and the random delivery time τ is defined as:

$$\tau(F_\tau) = \inf(s \in [t, \infty) \mid F_s = F_\tau).$$

Equation (4) states that, whenever $P_t > F_t$, it will be profitable for the supplier to infringe the contract delivery date. In particular, for any given c, the supplier will be better off by maximizing (4) with respect to F_τ in order to determine the optimal delay. The net benefit that will trigger the supplier's investment is:[10]

$$F_\tau = 1 - \frac{\beta}{\beta - 1}(1 + \pi\frac{c}{r}) \tag{5}$$

Equation (5) yields the following investment rule: if $F_\tau \leq F_t$, it is optimal for the supplier to comply with the contractual time (i.e. deliver the works immediately), whereas if $F_\tau > F_t$, it is optimal to wait until the NPV equals F_τ.

[9] The solution to $E_t(e^{-r(\tau-t)})$ can be obtained by using dynamic programming (see, for example, Dixit *et al.*, 1999). Since F_t is driven by a Geometric Brownian Motion, the expected discount factor is increasing in F_t and decreasing in F_τ; then it can be defined by a function $\Lambda(F_t; F_\tau)$. Over the infinitesimal time interval $t + dt$, F_t will change by the small value dF_t, hence we get the following Bellman equation: $r\Lambda(F_t; F_\tau)dt = E(d\Lambda(F_t; F_\tau))$. By applying Itô's Lemma to $d\Lambda$ we obtain the following differential equation:

$$\frac{1}{2}\sigma^2 F_t^2 \Lambda'' + \alpha F_t \Lambda' - r\Lambda = 0\,,$$

which can be solved by imposing the two boundary conditions: $\lim_{F_t \to \infty} \Lambda(F_t; F_\tau) = 0$ and $\lim_{F_t \to F_\tau} \Lambda(F_t; F_\tau)) = 1$. The general solution is $\Lambda(F_t; F_\tau)) = \left(\frac{F_t - 1}{F_\tau - 1}\right)^\beta$, where $\beta < 0$ is the negative root of the auxiliary quadratic equation $\Psi(\beta) = \frac{1}{2}\sigma^2\beta(\beta - 1) + \alpha\beta - r = 0$.

[10] The first order condition is:

$$\begin{aligned} \frac{\partial P}{\partial F_\tau} &= \beta\left(\frac{F_t - 1}{F_\tau - 1}\right)^{\beta - 1}\left(-\frac{F_t - 1}{(F_\tau - 1)^2}\right)\left(F_\tau + \pi\frac{c}{r}\right) + \left(\frac{F_t - 1}{F_\tau - 1}\right)^\beta \\ &= \left(\frac{F_t - 1}{F_\tau - 1}\right)^\beta \left[\beta\left(-\frac{1}{F_\tau - 1}\right)\left(F_\tau + \pi\frac{c}{r}\right) + 1\right] = 0 \end{aligned}$$

Using (5), we can calculate the maximum amount per day that the supplier is willing to pay for not complying with the contractual delivery time. This is given by the value of c^* that makes the supplier indifferent between P_t and F_t, i.e.:

$$c^* = \frac{r}{\pi}\left(\frac{\beta - 1}{\beta}C_t - 1\right) \tag{6}$$

Note that, if the supplier expects a low probability π and/or high current production costs C_t (i.e. for a decreasing NPV), the supplier's option value to delay increases. Further, since $d((\beta - 1)/\beta)/d\sigma > 0$, we get the same result for increasing uncertainty.

3 Time overruns in Italian PPCs

To investigate supplier strategic delays in PPCs and test our theoretical model's predictions, we used the database compiled by the AVCP. This database records information on all Italian public works contracts worth between Euro 150,000 and Euro 15,000,000 awarded by municipalities, local/regional public authorities and public firms. Descriptive statistics of this dataset[11] highlight that out of 45,370 fully completed contracts in the period 2000-2006, about 35,312 (corresponding to about 78%) were completed with delays. The average delay was about 157 days and the maximum delay greater than 1500 days.

[11] For more detail on the descriptive analysis conducted on the AVCP's dataset see D'Alpaos *et al.* (2009).

	Description	N of contracts	N delayed contracts (percentage)	Average days	Average delayed days	S.d. delayed days
PRO	"Open procedure"	30244	24047 (80%)	412.8	153.6	205.3
	"Negotiated procedure"	13189	9926 (75%)	399.7	151.4	223.9
	n.c.	1958	1345 (69%)	262.9	95.7	1632
By range value (Euro)	150 to 500	31837	24115 (76%)	336.0	131.8	189.8
	500 to 1000	7718	6327 (82%)	483.1	173.2	225.9
	1000 to 5000	5336	4175 (78%)	641.6	219.9	260.5
	5000 to 15000	373	313 (84%)	854.4	267.1	291.7
	> 15000	106	82 (77%)	929.4	213.9	353.9
Types of Works	Cultural goods	4499	3840 (85%)	450.2	186.1	220.6
	Building construction	14679	11634 (79%)	430.7	148.1	202.3
	Railways	835	484 (58%)	350.7	61.3	268.5
	Infrastructures	2904	2274 (78%)	421.2	160.9	223.4
	Environmental protection, Soil conservation, Water Resources	5833	4579 (79%)	417.5	172.9	229.5
	Roads	16488	12397 (75%)	248.5	137.9	196.3
	n.c.	132	104 (79%)	361.2	126.4	247.1
Types of CA	Public Administrations	2428	1683 (69%)	375.3	122.9	212.5
	National Roadworks Board (Anas)	340	150 (44%)	218.9	9.1	102.1
	the National Health Service	1262	955 (76%)	485.7	165.2	234.9
	Municipalities	23394	19552 (84%)	411.5	170.4	208.3
	Concessionaires and administrator of public infrastructure and networks	3142	2232 (71%)	398.2	118.8	201.1
	Public corporations and other public organizations	2949	2372 (80%)	445.8	166.8	219.4
	National Railways	891	507 (57%)	347.4	65.9	269.8
	the Council Housing Board (IACP)	1595	1182 (74%)	556.8	160.7	231.4
	Postal Services	354	264 (75%)	154.1	49.2	80.4
	Provincial Authorities	6863	4715 (69%)	340.1	110.2	174.9
	Regional Authorities	1861	1492 (80%)	427.3	192.7	242.9
	n.c.	291	208 (71%)	328.4	69.9	146.6
	Total	45370	35312 (78%)	402.6	150.6	209.6

Table 1: Descriptive statistics performed on AVCP database.

Table 1 summarizes the main features of these contracts according to: *i)* the awarding procedure (open, negotiated and non-classified - n.c.);[12] *ii)* their awarded values (grouped into four classes of value ranges: from Euro 150,000 to Euro 500,000; from Euro 500,000 to Euro 1,000,000; from Euro 1,000,000 to Euro 5,000,000; from Euro 5,000,000 to Euro 15,000,000; larger than Euro

[12] In Italy, before the Governmental Decree no. 163/2006, PPCs were regulated by Law no. 109/1994 and Presidential Decree no. 554/1999, which defined the main awarding procedures as: "pubblico incanto", "licitazione privata", "licitazione privata semplificata" and "trattativa privata". The "pubblico incanto" is an open pocedure in which any firm certified as being qualified to do the works involved can participate. The "licitazione privata" and "licitazione privata semplificata" are similar to the "pubblico incanto" except that participants are invited by the CA providing they satisfy certain technical characteristics. The "trattativa privata" is a private negotiation where the CA invites a limited number of participants (minimum 15). The AVCP dataset records the awarding procedures in accordance with legislation applicable at the time (between 2000 and 2006 in our case). We grouped the data into two main awarding procedure groupings: i.e. "open" and "negotiated" procedures. In our regression analysis we created a dummy variable where the open procedure equates to 1.

15,000,000); *iii)* the different "types of works" awarded to the suppliers, i.e. "cultural goods", "environmental protection", "soil conservation", "water resources", "roads", "railways", "infrastructure" and "building constructions" and iv) the different types of CA awarding PPCs.[13] In particular Table 1 displays information about the number of contracts, the average number of delayed days, the average number of days necessary for execution of the works, and the standard deviation of the recorded delay.

We can observe (Table 1) that firstly most of the contracts are of small value, in fact more than 60% of the total PPCs recorded in the dataset fall in the range between Euro 150,000 and Euro 500,000), and secondly the PPCs awarded with an open procedure are more than double those awarded with a negotiated procedure. The majority of the contracts awarded involve two works categories: "building constructions" and "roads" amount to 32% and 36% of the total respectively. If we compare the analysis of these two subgroups with the entire dataset we find that the category "roads" presents lower average delays and fewer delayed contracts than the entire set, while the descriptive statistics for "building constructions" are similar to those of the entire set. As far as the CA types are concerned, the analysis shows that the Municipalities award the largest number of contracts (52% of the total) showing a higher number of delayed contracts and a higher delay length than the average levels of the dataset. Moreover, considering the number of delayed contracts with respect to the awarding procedure, no very big differences are found: out of the 30,244 contracts awarded with an open procedure, about 80% recorded delays, and analogously out of the 13,189 contracts awarded with negotiated procedures, about 75% recorded delays.

In order to focus geographical variability and highlight some useful insights into the dataset, especially with respect to the three different Italian macro-regions (i.e. Northern, Central and Southern Italy),[14] in Figure 1 we plot the ratio between the average number of days of delay over the contracted number of days for different contract value ranges and the different macro-regions where the contracts were awarded. Figure 1 shows that except for high contract values there is no significant difference between the three macro-regions in terms of this ratio. The exception is Southern Italy which records higher ratios than Northern and Central Italy for the two highest-range value contracts (i.e for contract values larger than Euro 5,000,000).

[13] Among the various types of Italian CA, we considered: Public Administrations, Regional Authorities, Territorial Associations in Mountain Regions, Provincial Authorities, Municipalities, the National Health Service, National Railways, National Roadworks Board (Anas), Postal Services, public corporations and other public organizations, concessionaires and administrators of public infrastructures and networks, and the Council Housing Board (IACP).

[14] The geographical distinction into macro-regions has been made referring to the definition provided by the Italian National Institute of Statistics (ISTAT) which divides Italy into three macro-regions: 1) Northern Italy (which comprises Piedmont, Valle d'Aosta, Liguria, Lombardy, Trentino Alto Adige, Veneto, Friuli-Venezia Giulia, Emilia Romagna); 2) Central Italy (which includes Tuscany, Umbria, Marche and Lazio); 3) Southern Italy (which is composed of Abruzzo, Molise, Campania, Puglia, Basilicata, Calabria, Sicily and Sardinia).

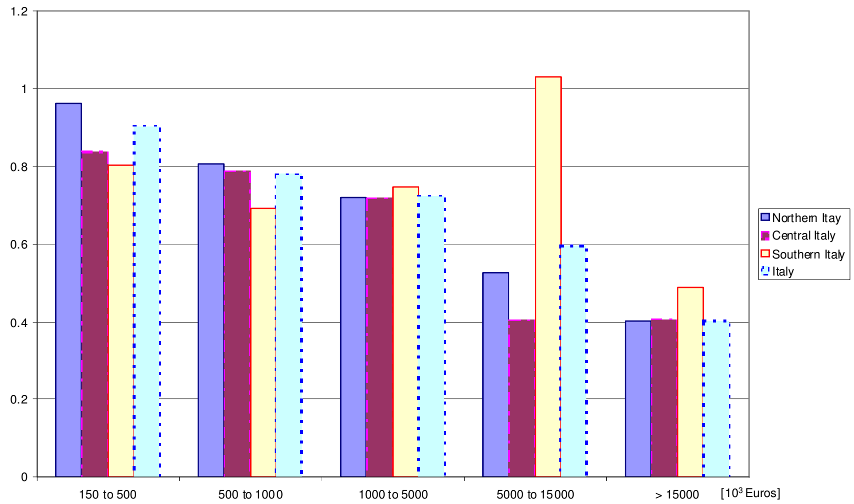

Figure 1: Average number of delayed days over number of contracted days according to contract location and value ranges.

The AVCP's dataset enabled us to test the determinants of time overruns as predicted in the previous section. Below we run simple regressions to test whether, among other variables, the variance of production costs and the "efficiency" of the judicial system affect time overruns.

We estimate the following regression function with some control variables:

$$\mathrm{DD}_{igt} = \alpha + \beta_1 \mathrm{COV}_{igt} + \beta_2 \mathrm{JUS}_{rt} + \beta_3 \mathrm{CVA}_{igt} + \beta_4 \mathrm{CDA}_{igt} + \beta_5 \mathrm{PRO}_{igt} + \mathrm{X}'_{it}\gamma + \eta_g + \nu_t + \varepsilon_{igt} \tag{7}$$

The dependent variable is the number of days of delay (*DD*) in completion of the public works (i), in a given province (g), and year (t), and corresponds to the difference between the number of days actually taken to complete the contracted works and the number of days specified in the contract.

The independent variables are as follows: i) contract value (*COV*); ii) justice (*JUS*); iii) cost variance (*CVA*); iv) contracted days (*CDA*); and v) awarding procedure (*PRO*). We also introduce: η_g and ν_t for groups of provinces and time fixed effects and X for observable works-specific characteristics.

The *COV* variable is the contract value (i.e. the price at which the contract has been awarded), while *JUS* indicates the "efficiency" of the Italian judicial system. As in Jappelli *et al.* (2005) and Coviello *et al.* (2011), we measure *JUS* as the average time taken to complete civil trials, so a higher *JUS* value means a less efficient judicial system and in turn a less efficient contract enforcement. Data on the duration of civil trials were obtained from the Italian National

Statistics Institute (ISTAT) at regional level (r), by year (t), for the 2000-2006 period.

Since the supplier's production costs are not recorded in the AVCP dataset, to measure the cost variability (*CVA*), we calculate a weighted average standard deviation by using COV relative to the five contract range values as presented in the above Table 1.[15] We justify this choice on the grounds that: a) public works contracts are awarded mainly through open or negotiated procedures where the CA reveals its production cost estimate to all the potential suppliers in the form of reserve price[16]; b) for most public works categories the supplier's cost structure is the sum of an idiosyncratic component and a common component. The idiosyncratic costs are relatively straightforward and depend basically on a given firm's equipment and internal efficiency, while the common costs are more volatile and their uncertainty affects all bidders (e.g. soil conditions at the site not perfectly known until digging begins, changes made to the contracted quantities of certain work items, variations in the price of materials, equipment rental rates, or labor costs).

Then, the larger the proportion of the total estimated costs attributable to this common component, the more the variance of the contracts' prices represents a good proxy of the variability of production costs. Indeed, if the works in a given category are highly standardized, the suppliers would be perfectly homogeneous, and the variability of the contract prices should be almost exclusively attributable to the variance of the common costs component.

Furthermore *CDA* indicates the days established in the contract for completion of the works; *PRO* is a dummy variable indicating the awarding mechanism, distinguishing between "open" and "negotiated". Finally X includes: a) the different types of CA awarding PPCs; b) the different "types of works" awarded to the suppliers.

We estimate equation (7) including time, province, CA and works fixed effects, and by clustering the standard errors at geographical level for the whole available sample.

Table 2 shows the standardized βs and the corresponding t-stat for each variable in four different regressions. According to our theoretical model (Section 2), the higher the production cost variance, the higher the supplier's option value to delay the investment: we thus expect a positive and significant β coefficient.[17] In detail, Column 1 shows the regression with fixed effects for province,

[15] For the sake of clarity it should be pointed out that the empirical model is not a direct estimate of the theoretical model but rather an attempt to verify the model's theoretical predictions.

[16] The CA production costs estimate is calculated by engineers from the bill of quantities (i.e. a document containing an analytical and detailed statement of the different items of the works, labor and materials, including a contingency sum, involved in a proposed public works). This estimate is used to establish the reserve value in the contract awarding procedure and as a benchmark to assess the bids submitted and identify abnormally low bids (see Italian Governmental Decree no. 163/2006).

[17] In our regression, we found that *COV* and *CVA* are positive, and since they might be both affected by the option value (even if *COV* might be affected by the option value, *CVA* by its variability), we checked for collinearity. All the tests (tollerance, VIF and collinearity diagnostics) confirmed the absence of collinearity in our regression (these tests are available on

year, type of public works and type of CA; Columns 2, 3 and 4 discard the fixed effects for province, type of works and CA respectively, *ceteris paribus*.[18]

Model	1		2		3		4	
Variables	β	t-stat	β	t-stat	β	t-stat	β	t-stat
COV	0.063 (***)	13.71	0.075 (***)	15.27	0.062 (***)	13.5	0.059 (***)	15.75
JUS	1.079 (***)	72.01	0.83 (***)	16.91	1.073 (***)	72.32	1.081 (***)	72.61
CVA	0.014 (***)	3.19	0.021 (***)	4.419	0.013 (**)	2.97	0.014 (**)	3.10
CDA	-0.170 (***)	-35.40	-0.099 (***)	-19.86	-0.165 (***)	-34.4	-0.166 (***)	-34.70
PRO	0.012 (**)	2.34	-0.022 (***)	-4.667	0.07	1.48	0.07 (***)	3.108
Year fe	Yes		Yes		Yes		Yes	
Work fe	Yes		Yes		No		Yes	
Contractor fe	Yes		Yes		Yes		No	
Province fe	Yes		No		Yes		Yes	
R^2	0.208		0.08		0.202		0.193	

Table 2: Regressions with number of days of delay as the dependent variable. Significance levels: (*)=90%; (**)=95%; (***)=99%

Our empirical analysis on Italian PPCs is consistent with the theoretical model's predictions. In all regressions the number of days of delay are positively correlated to *CVA* and *JUS* and are statistically significant. This evidence supports our model's predictions that suppliers endogenize their decision about the investment timing of the contract taking advantage of the gains deriving from both the variance of the production costs and the inefficiency of the judicial system in enforcing the penalties.

Our regressions also show that delays are positively affected by the value of the contract (*COV*) and negatively affected by the number of contracted days (*CDA*), while the *PRO* variable has an ambiguous sign.[19] Thus, while establishing a longer contract delivery time reduces the delays, high contract values and open procedures determine the opposite effect, increasing delays. Since the largest complex contracts include the most unpredictable events (e.g. unexpected site conditions, bad weather, poor project planning, or late delivery of materials) which might delay the works, relaxing the contract time may prove

request). A possible explanation for this absence of collinearity might be that *COV* captures the dimension of the project (larger works implying longer delays), while *CVA* captures the option value (higher cost variability meaning longer delays).

[18] The regressions in Table 2 and Table 3 were completed with SPSS software: the same results emerged by using Stata software, but in this latter case, the standard errors were clustered by regions.

[19] *PRO* is significant in regressions 1, 2 and 4, but it is not in regression 3. It also has a sign that is sometimes positive and sometimes negative. In particular, when we discard the province fixed effect, the significance of *PRO* is null. This may be because the province is an important variable and ruling it out generates an omitted variable bias, making the estimate unreliable.

to be more efficient than trying to describe the project more accurately (Bajari and Tadelis, 2001).[20]

Next, to further investigate the effect of cost variance, we run some regressions for sub-samples defined by the "range value" (in thousands of Euro) and the "type of works", and we present the results in the lines and columns of Table 3. As mentioned above, if, within a given works category, the suppliers executing the contracts are homogeneous, the variance in the idiosyncratic cost component should be null, and the variance of the contract prices captures the variance of the common costs component. If this is the case, we expect CVA to be significant only in standardized works categories.[21]

For each sub-group, we checked for the Chow test[22] and estimated (7). Table 3 shows the level of the significance for CVA. The regressions show that the relation is significant (last line in Table 3) for the following groups of works: "roads", "railways", "infrastructure", "building constructions". We also found a strong significance in the low value ranges (for contracts worth Euro 150,000 - 500,000 or Euro 500,000 - 1,000,000) and for the works relating to "cultural goods", "roads" and "railways" worth Euro 1 to 5 million, which in total accounted for 87% of the whole dataset (39,555 contracts of the 45,370 considered). Since lower-value works are generally standard and more simple,[23] our empirical results support the idea that cost variance is more important for these works, becoming non-significant for types of works with particular characteristics.

Range Value\Work	Cultural Goods	Environmental	Roads	Railways	Infrastructures	Buildings	All
[150; 500)	(**)	(***)	(**)		(**)	(**)	(***)
[500; 1000)				(***)		(**)	(**)
[1000; 5000)	(**)		(**)	(**)			
[5000; 15000)		(***)			(**)		
≥ 15000	(*)						
All			(***)	(**)	(**)	(***)	

Table 3 : Significance levels of CVA, for each type of works and value range.

[20] Comparing the four regressions, we see that R^2 decreases when we do not control for the province fixed effect, while it is similar in the other cases: this may mean that local conditions significantly affect the execution time.

[21] This is also consistent with some recent theoretical and empirical contributions on procurement auctions. Goeree and Offerman (2003) demonstrated that bidding competition is more aggressive in auctions with larger common cost uncertainty and Dosi and Moretto (2012) show that an option value to delay the execution of a project can be generated by the uncertainty over the common component of the construction costs. De Silva *et al.* (2008) empirically showed a marked decline in the value of bids for highway procurement auctions when the common uncertainty about the costs was great and the CA's internal estimate of the project cost was revealed to all bidders.

[22] We performed a Chow test I for the contract value range, obtaining an F test result of 112 and a p-value of 0.000, and a Chow test II for the contract value range, obtaining an F test of 15.72 and a p-value of 0.000.

[23] Bajari and Tadelis (2006) use the term "simple" to denote a project which is "easy to design with little uncertainty about what needs to be produced" (p. 124).

4 Numerical study

We conclude the paper by analysing the trade-off between the supplier's option value to defer and the value of the penalties to be paid. We specifically investigate this trade-off referring to the penalties as set by the Italian legislation on PPCs. In this respect, we calculate the amount the supplier is "willing to pay" to postpone the delivery date, calibrating (6). In particular as the CA and the supplier should refer to a court of law to settle any dispute concerning the committed penalty, we assume that π depends on: a) the court's discretion in reducing or even not enforcing the penalties; b) the "efficiency" of the judicial system. If the court considers the penalty demanded "excessive", it may decide not to enforce it or to reduce it to a value judged reasonable to cover the damages caused by the supplier's breach.[24] We model this discretion by assuming that π is a function of c with the properties $\pi'(c) < 0$, $\pi(\underline{c}) = 1$ and $\lim_{c\to\infty} \pi(c) = 0$, where $\underline{c} \geq 0$ represents the minimum per-day penalty (i.e. the time unit value) that the court considers "reasonable" as foreseen *ex ante* by the supplier.[25]

To investigate how the "efficiency" of the judicial system affects the enforceability of the penalty clause, following Guasch *et al.* (2006, p. 60), we multiply $\pi(c)$ by a parameter $\theta \in [0, 1]$ that refers to the average time taken by the court to solve disputes. In other words, we assume that - on average - the supplier's expected penalty will be lower the longer it takes to reach a verdict in a civil trial. Based on these assumptions (6) becomes:

$$\pi(c^*)c^* - \frac{r}{\theta}\left(\frac{\beta-1}{\beta}C_t - 1\right) = 0, \qquad for \;\; c^* \geq \underline{c}. \tag{8}$$

Referring to the Italian setting, we provide some numerical solutions for c^* (Tables 4, 5). We further specify different values for θ according to the data on the average length of ordinary civil trials in different Italian regions and compare Northern and Central Italy with Southern Italy.

Regarding the probability of enforcement, we assume $\pi(c) = (\underline{c}/c)^\eta$ for $c \geq \underline{c}$. In other words, when the CA sets a penalty higher than $\underline{c}$, an increase in elasticity η determines a rapid decrease in π. If the elasticity is less than one, so that higher values of $\underline{c}$ are deemed excessive by the court, increasing values of both σ and C_t lead to higher c^*. In the numerical simulation, $\underline{c}$ takes the

[24] This discretionality of the court is commonly referred to as the "liquidated damages principle" (DiMatteo, 2001). Delay in delivering the contracted investment should be referred to a specific case of the supplier's breach of contract, and the court can apply the above principle to cover the reasonable damages caused to society by delays. For a discussion of the application of the "liquidated damages principle" in PPCs, see Dimitri *et al.* (2006, Ch. 4, pp. 85-86); for an analysis of the economic incentives pertaining to it, see Anderlini *et al.* (2007).

[25] In the US experience of PPCs in the highway construction industry, the "unit time value" is typically expressed as a cost per day. It is calculated by the State Highway Agency referring to the "daily road-user cost", which includes items such as travel time, travel distance, fuel expense, etc. See Herbsman *et al.* (1995) for an example of the "daily road-user cost" calculated by the Kansas Department of Transportation.

values of 0.03% per day (i.e. 10.95% per year) and 0.1% per day (i.e. 36.5% per year), which are respectively the lower and upper limits of the penalty in PPCs as set by the Italian legislation,[26] while the elasticity is $\eta = 0.5$.

Consequently, equation (8) now becomes:

$$c^* = \max \left\{ \underline{c} \ , \ \frac{\left[r/\theta \left(\frac{\beta-1}{\beta} C_t - 1 \right) \right]^{1/1-\eta}}{(\underline{c})^{\eta/1-\eta}} \right\} \tag{9}$$

The calibration parameters follow, as closely as possible, the indications in related studies (Dixit and Pindyck, 1994; Herbsman *et al.*, 1995; Arditi *et al.*, 1997). As mentioned previously, the price of the contracted investment is normalized to one; the discount rate (expressed in yearly terms)[27] is $r = 5\%$; the investment costs amount to $C_t = 0.7, 0.8, 0.9$ [28]; the drift (expressed in yearly terms) is $\alpha = 3\%$[29] and the variance of the costs is $\sigma = 0.3, 0.4, 0.5$. Finally, interpreting θ as the probability of a court solving a dispute within a year, we set $1/\theta = 3$ to refer to the average number of years Italian courts take to solve legal disputes according to ISTAT data.

Table 4 illustrates the value of c^* for $\underline{c} = 0.03\%$, while Table 5 displays the values of c^* for $\underline{c} = 0.1\%$.[30]

Our calibrations show that the higher the investment cost, C_t, and/or the uncertainty, σ, the greater the supplier's value to delay the investment and also that the lower the probability π of the supplier paying the penalty (that is, the higher $\underline{c}$ and the lower the "efficiency" of the judicial system), the greater the supplier's value to delay the investment. In addition, it is evident that c^* is highly sensitive to $\underline{c}$. Specifically, when the value of the per-day penalty that the court considers "reasonable" is $\underline{c} = 0.03\%$, Table 4 shows that c^* always exceeds $\underline{c}$ except for very low values of σ. By contrast, when $\underline{c} = 0.1\%$ (Table 5), c^* is only higher than 0.1% for high values of σ.

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[26] Italian legislation sets maximun and minimum penalties for the inclusion in PPCs. The per day penalty can range from 0.03% to 0.1% of the contract price. See Governmental Decree no. 163/2006 and Presidential Decree no. 270/2010. See in particular art. 145 Presidential Decree no. 270/2010.

[27] Although r should be the return that an investor can earn on other investments with comparable risk characteristics, throughout our analysis we simply refer it to the social discount rate recommended by the Italian Government for use in assessing most public projects. For Italy, r ranges between 8% and 12%, possibly dropping to 5% for projects undertaken in the south of the country (see Pennisi and Scandizzo, 2003).

[28] To emphasize the effect of the contract's profitability on the supplier's decision concerning the delivery date, we fix the mark-up at 30%, 20% and 10%.

[29] $\alpha = 2.5\% - 3\%$ is the average trend of the increase in costs for public infrastructure and residential buildings from 1996 to 2006. The data used to estimate this trend were provided by the ISTAT.

[30] Simulations were conducted also ceteris paribus for $\eta = 0.5$ and for r=10%. Results are available on request to the authors.

α=0,025		c*			
		r=5%			
		σ=20%	σ=30%	σ=40%	σ=50%
C_t	0,9	0,0560%	0,3036%	0,9300%	2,1891%
	0,8	0,03%	0,1778%	0,6227%	1,5552%
	0,7	0,03%	0,0855%	0,3769%	1,0295%

Table 4: c^* for different values of C and σ, $\underline{c} = 0.03\%$, $\theta = 1/3, \alpha = 0.3$, $r = 5\%$, $\eta = 0.5$ expressed as a percentage and in terms of days.

α=0,025		c*			
		r=5%			
		σ=20%	σ=30%	σ=40%	σ=50%
C_t	0,9	0,1%	0,1%	0,2790%	0,6567%
	0,8	0,1%	0,1%	0,1868%	0,4666%
	0,7	0,1%	0,1%	0,1131%	0,3088%

Table 5: c^* for different values of C and σ, $\underline{c} = 0.1\%$, $\theta = 1/3, \alpha = 0.03$, $r = 5\%$, $\eta = 0.5$ expressed as a percentage and in terms of days.

In other words, if the court, at the time of contracting, considers a per-day penalty of 0.1% a "reasonable" estimate of the damages caused by the supplier's breach (i.e. the daily social cost), barring cases where the volatility of the costs is particularly high, the supplier's value to delay (i.e. the supplier's willingness to pay for postponing the execution time), corresponds exactly to $\underline{c}$. Therefore, if the CA establishes in the contract that $c = 0.1\%$, it will generally be able, on average, to cancel the option value for the supplier of delaying the works, while simultaneously ensuring the perfect enforceability of the penalty clause.[31]

Conversely, if the court reduces the amount of the per-day penalty, the supplier's option to delay increases. In particular, if the court judges a penalty corresponding to $\underline{c} = 0.03\%$ "reasonable" (at the lower end of the range of penalties allowable by Italian law), for the supplier it is always profitable to delay the works. In this case, the CA faces a trade-off between the decision to set c higher than $\underline{c}$ to ensure the supplier's compliance with the established deadline and risk this penalty not being enforced by the court, on the one hand, and the decision to set $c = \underline{c}$ and suffer delays, on the other. In this latter case, the CA collects $\underline{c}$ while the supplier gains $c^* - \underline{c}$.

Finally to analyse in greater detail the effects of the "efficiency" of the judicial system on c^*, we consider the length of ordinary civil trials in the three Italian macro-regions as reported in the dataset provided by the Italian Ministry of Justice in 2005. According to the data provided both by the Ministry of

[31] Note that all the results according to which the CA finds it convenient to set the penalty as equal to $\underline{c}$ are highlighted in yellow in the Tables.

Justice and ISTAT at regional level, the average length of trials in Northern and Central Italy is 646 days and 648 days respectively, while in Southern Italy it is 1015 days. In the entire period 2000-2006 the average length is analogous in Northern and Central Italy (NCI henceforth) while it differs in Southern Italy (SI henceforth), about twice as long.[32] Therefore in order to investigate, *ceteris paribus*, the differences in terms of c^* between these two geographical areas, we set $\alpha = 0$[33] and assume $\theta = 0.5$ for NCI, and $\theta = 0.25$ for SI. These parameters account for the empirical evidence that the average time taken to complete ordinary civil trials is about 2 years in NCI and 4 years in SI.

Figure 2 below illustrates the results of the simulations when $\underline{c} = 0.1\%$, $\alpha = 0$, $r = 5\%$ and $\eta = 0.5$.

By direct inspection of Figure 2, it is easy to show that c^*decreases for increasing values of θ. In other words, c^* is always greater for PPCs awarded and executed in SI than for those in NCI. The spread between NCI and SI also increases for increasing values of C_t and σ. Note, for example, that when $\underline{c} = 0.1\%$, $\alpha = 0$, $r = 0.05$, $C_t = 0.9$ and $\sigma = 40\%$, the option value to delay is twice as high in SI than in NCI. In particular when $\eta = 0.5$ then $c^* = 0.29\%$ in NCI, and $c^* = 0.58\%$ in SI.[34]

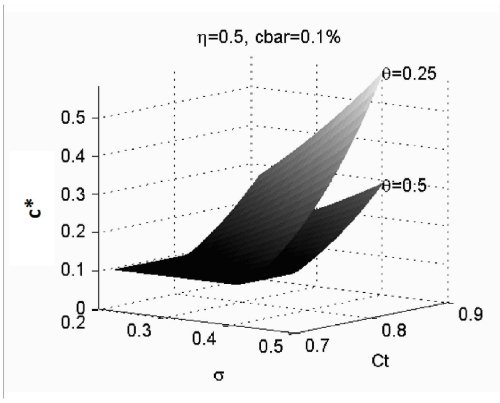

Figure 2: c^* expressed as a percentage and in terms of days for $\underline{c} = 0.1\%$, $\eta = 0.5$, with respect to increasing σ and C_t.

[32] For a more extensive analysis on the length of civil trials in Italy see D'Alpaos *et al.* (2009).

[33] We set $\alpha = 0$ to neutralize the effects of inflation and to focus only on regional effects.

[34] These findings are confirmed, *ceteris paribus*, for $\eta = 0.3$ where $c^* = 0.11\%$ in NCI while $c^* = 0.22\%$ in SI. Results are available on request to the authors.

5 Conclusions

Public procurement contracts account for a huge volume of economic activity in many countries, and the abundant evidence of harmful delays in the delivery of the contracted investments makes the issue worth investigating. Uncertainty in the estimated production costs determines significant risks and opportunities, which may induce suppliers to adopt an opportunistic behavior in the form of time overruns.

In executing the contract, i.e. in making an irreversible investment, suppliers may find it optimal to delay the execution of the works if they expect higher payoffs in the future.

To prevent suppliers' strategic delays in delivering the contracted works, public buyers usually include a penalty clause in the contract. Whether or not such a penalty is effective in limiting the supplier's opportunistic behaviour typically depends on the committed fee level and on its enforcement by the court of law to which the parties refer to settle any dispute. The enforcement of the penalty typically depends on both the discretion of the law courts in voiding contractual clauses and the "efficiency" of the judicial system (i.e. the length of civil trials).

In this paper, we investigate whether, irrespective of any penalty clause included in the procurement contract, the uncertainty over investment costs creates an incentive to adopt an opportunistic behavior and thus generate strategic time overruns.

We tested our model's predictions on the AVCP's dataset. Introducing a proxy for the variance of production costs our empirical findings are consistent with the theoretical results. Furthermore, the numerical simulations also show that the option value to delay is very sensitive to the "efficiency" of the judicial system and to the discretion of the court in reducing or even not enforcing any penalties incurred. As the "efficiency" of the judicial system differs between Northern-Central Italy and Southern Italy, our results proved that the supplier's option value to delay is always greater for public procurement contracts awarded and completed in Southern Italy than for those awarded in Northern-Central Italy. In addition, the spread between the option value to delay in Northern-Central Italy versus Southern Italy increases when uncertainty over the construction costs and the values of the contracted works increases.

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