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Summary

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Keywords: Strategic Time Overruns, Public Procurement, Real Options

JEL Classification: D81, H54, H57, L51

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Time Overruns as Opportunistic Behavior in Public Procurement*

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Abstract

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1 Introduction

The deterioration of public finance and the increase in global competition have forced governments and public institutions to obtain "the best value for money" through the purchase of goods, works and services by means of procurement contracts. Efficient public procurement contracts (PPCs, henceforth) are thus emerging as a "core necessity for the public sector's effectiveness in obtaining resources for social spending and/or lowering taxes" (Dimitri *et al.*, 2006). In recent years, it has been confirmed that public procurement represents a big business, accounting for a significant part of national economies: the European Commission estimated that in 2011 public procurement represented up to 19% of the European Union's GDP (European Commission, 2012) and public procurement transactions in the United States in recent years was around 20% (Dimitri *et al.*, 2006).

Public procurement is a versatile mechanism that can efficiently convey public resources to private operators, but its benefits (in terms of allocative and productive efficiency) 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 between the supplier and the buyer (Laffont and Tirole, 1993): the former holds an information advantage over production costs and this represents the main source of inefficiency in contracting. The seminal paper by Bajari and Tadelis (2001), modeling the tension between ex-ante incentives and ex-post transaction costs due to costly contract renegotiation, represents the first analysis considering both ex-post adaptation and ex-ante screening in procurement.[1] Differently, engineering and construction management literature tends to concentrate on the effects that the volatility of the production costs has on the supplier's bidding strategy (Crowley and Hancher, 1995; Levin 1998; Xu and Tiong, 2001). In particular, uncertainty on estimated investment costs give rise to significant risks and opportunities which may prompt suppliers to adopt an opportunistic behavior, such as under-pricing and time overruns (King and Mercer, 1985; Chapman et al. 2000; You and Tam, 2006; Lo, Lin and Yan, 2007). Opportunistic behavior can be interpreted in this setting as an offer strategy by the contractor firm. In executing a contract, i.e. in making an irreversible investment, suppliers may find it optimal to delay the performance of the works in the hope of gaining higher payoffs in the future. This flexibility may increase the contract's value and enable suppliers to offer lower prices when bidding for the project.

To prevent the arise of strategic time overruns, buyers usually include a penalty clause in PPCs, specifying the amount of compensation due for delays

[1] In an interesting paper investigating time delivery in public procurement, Lewis and Bajari (2011) used empirical evidence from a dataset of Californian highway projects to show that, when the delivery time is an issue, an auction designed to score potential supplier's bid on costs to execute the contract along with the project completion time is more efficient than an auction where participants bids exclusively on price.

beyond the agreed delivery date. Whether or not such a penalty has a role in containing the adoption of strategic behavior typically depends on the committed fee and on the enforcement of this contractual liability by the court of law to which the parties refer to settle any disputes.

In this paper we investigate whether the perceived uncertainty over construction costs and the flexibility to delay a project act as an incentive to adopt an opportunistic behavior. In the specific 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 incurred. We include in our model both the discretion of the court of law in enforcing contractual clauses (i.e. the penalty for delays) and the "quality" of the judicial system (i.e. the length of court trials). Then, we calibrate the model using parameters that mimic the Italian scanario for PPCs and calculate the maximum amount that a firm is "willing to pay" (per day) to postpone the delivery date.

We base our analysis on two main tested hypotheses. First, we show that the higher is the variability of construction costs, the stronger is the incentive to delay. Second, we demonstrate that the incentive to delay is magnified in setting - such as the Italian one - where the Contracting Authority (CA) has little or no chance of seeings the penalties enforced because the "quality" of the judicial system is low and/or the discretion of the court of law is large. Contractual penalties may consequently not represent significant losses to the defaulting party because the implementation of any legal sentence is too slow or weak, or because the penalty to pay is small by comparison of the option value to delay the works.

The theoretical argument that supports our first hypothesis is that a correlation exists between the variability of construction costs and the contractor's option value to wait for more information about the costs evolution before committing to an irreversible decision (Dixit and Pindyck, 1994). Indeed, if the construction costs are uncertain, a firm may delay starting a project in the hope of a cost reduction. In this case, even if delivering the works late were too entail a loss in monetary terms because there are penalties to be paid, the firm takes advantage in costs saving and benefits from an option value.

The argument supporting our second hypothesis is that in order to avoid costly and lengthy legal proceedings of uncertain outcome, the CA might decide not to claim the penalty in the event of delays. In fact, specifically referring to the Italian scenario, the enforceability of the agreed completion time is not straightforward. While on the one hand Italian legislation establishes that the CA has the right to oblige its contractor firm to pay a penalty in the event of delays, and it can exercise this right directly, on the other hand the contractor firm can claim that it has little or no responsibility for the delays in the completion of the works, and negotiate with the CA to pay only a part or even none of the enforceable penalty. This can happen, for instance, when delays are due to design errors, adverse weather conditions, or unpredictable events. The contractor firm may also 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).[2] It is at the CA's discretion in such cases to accept or reject its contractor's claims (art. 145 Presidential Decree n. 207/2010), and if it rejects them and demands the payment of the penalty, the contractor can take the matter to court. Although a legal action can be very costly and time-consuming for both parties (particularly in Italy where civil trials usually take a very long time), this is especially true for the CA because of the additional indirect costs relating to potential negative political effects. Because the court may decide to reduce, or even waive the penalty demanded by the CA (art. 1384 Italian Civil Code and Presidential Decree n. 207/2010),[3] the contractor will be more inclined to take the matter to court (so the CA becomes the defendant) and request an annulment or reduction of the penalties it has been asked to pay, while the CA might well prefer to exploit its degree of discretion to negotiate with the firm on penalty enforcement.

To our knowledge, the model described here is the first to investigate time overruns in a procurement setting as the result of the contractor firm's opportunistic behavior on the optimal investment timing where penalties are envisaged. By combining irreversible investment under uncertainty with strategic timing in executing procurement contracts, our paper mainly contributes to two strands of literature. First, and on a formal level, based on the value of flexibility in the firm's decision on optimal investment timing (Dixit and Pindyck, 1994; Trigeorgis, 1996), it adds to the existing literature with a novel application of the real option approach in the procurement setting. We complement this literature by providing a new investigation on strategic delivery decision in procurement as a Put Option. The 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), who argued that the rules governing contracts laid down by the Peruvian Government for the Antamina mine generated strong incentives for bidders to walk away from the project once they had won the auction. Monteiro da Silva Fenolio and Accioly Fonseca Minardi (2011) recently investigated the option value to delay for investors who obtained permission from the Brazilian Electricity Regulatory Agency to set up small hydroelectric power plants, and in the same vein Bastian-Pinto *et al.* (2012) demonstrated that delays in implementing investments in future

[2] Although legal literature is still debating the meaning and the role of penalty clauses, there has recently been a tendency to draw a more clear-cut distinction between clauses intended mainly to induce contractors to respect the terms of the contract and those designed to enable a genuine pre-assessment of the damages (McKenna, 2008). The latters invoke the liquidated damages principle, i.e. "Liquidated damages refer to a provision in a contract in which the parties agree to prevent litigation on the issue of damages in the event of breach. It is sometimes labeled as a stipulated damage clause or agreed damage. The law of liquidated damage refers to the particular body of principles developed by the common law that provide roadblocks to the parties ability to draft clauses that will be judicially enforced [...]. Liquidated damages clause is the more generic label with penalty being a sub-set. Also, penalty is used to designate those liquidated damages clauses that are unreasonable and unenforceable" (Di Matteo, 2001, pag. 633).

[3] See also the Resolution of Penalty Clauses, 78(3) adopetd by the Committee of Ministers on January 20, 1978.

energy generation in Brazil were attributable to investors' opportunistic behavior regarding energy concessions prompted by uncertainty over their future investment costs, and by an incomplete regulatory framework and low penalty enforcement. Finally, Dosi and Moretto (2012) showed that the perceived uncertainty over future project costs generates an option value of waiting which induces contractors to bid lower prices, in the expectation to opportunistically deviate from the contract provisions (i.e. to delay).

More broadly speaking, our model also contributes to the literature on judicial contractual enforcement, providing a theoretical framework in which the discretion of the court and efficiency of the judicial system matter. In a theoretical model developed by Guash *et al.* (2006) , the probability of contract enforcement is affected by a parameter referring to the "quality" (or efficiency) of the judicial system, where a less efficient judicial system coincides with a lower probability of contract enforcement. These theoretical predictions are broadly consistent with the empirical results obtained by the same authors on concession contracts for building infrastructure in Latin America (Guasch *et al.*, 2003). As shown by Djankov *et al.* (2003), in their exstensive empirical investigation on contract-related disputes in 109 countries, in countries where judicial enforcement is inefficient the proper completion of contracts is not ensured by courts. Eggleston *et al.* (2000) also highligted that the enforcement of contractual clauses can be limited when the cognizant law court has discretion in reducing (or even not enforcing) the penalties. A few analyses on the judicial enforcement of contractual terms in Italy have shown effects on the credit market and on the performance of public contracts. In particular Jappelli *et al.* (2005) found that more efficient judicial system reduces credit constraints and increase lending, while Coviello *et al.* (2011) presented empirical evidence of the effect of the efficiency of local courts on delays in the completion of PPCs.

This paper is organized as follows. In Section 2, we present empirical evidence drawn from a large dataset on Italian PPCs to demonstrate that: i) uncertainty over construction costs, and ii) the "quality" of the judicial system both significantly affect the recorded time overruns in the execution of the PPCs. In Section 3, we model the value of a PPC that includes the option-value to delay the works. Then, we calibrate our model using parameters that mimic the Italian scenario for PPCs to determine the option value to defer. In Section 4 conclusions are discussed.

2 Time overruns in Italian PPCs

Time overruns in the execution of PPCs are considerable in Italy. According to our descriptive analysis[4] of the database compiled by the AVCP (i.e. the Italian Authority responsible for controlling and monitoring PPCs), among 45,370 contracts registered between 2000 and 2006, about 78% were completed late. The average delay was about 157 days and the maximum delay more than 1500 days.[5]

The AVCP's dataset contains information on several aspects of each procurement contract, such as the awarding procedure, the type of public works, the price paid (i.e. the contract value), the established contract time and the final execution time. This dataset enabled us to test some hypotheses concerning the determinants of time overruns. To be specific, in this section we run simple regressions to test whether, among other variables, the variability of the construction costs and the "quality" of the judicial system affect time overruns.

We estimate the following regression function with some control variables:

$$\mathrm{DD}_{igt} = \alpha + \beta_1 \mathrm{COV}_{igt} + \beta_2 \mathrm{JUS}_{rt} + \beta_3 \mathrm{CVA}_{igt} + \beta_4 \mathrm{CDA}_{igt} + \beta_5 \mathrm{PRO}_{igt} + \mathrm{X}'_{it}\gamma + \eta_g + \nu_t + \varepsilon_{igt} \tag{1}$$

The dependent variable is the days of delay (DD) in the 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 project and the days specified in the contract.

The independent variables are as follows: i) contract value (COV); ii) justice (JUS); iii) cost variability (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 "quality" of the Italian judicial system. We measure JUS based on information on the average time taken to complete civil trials, so a higher JUS value means a less efficient legal contract enforcement. Data on the duration of civil trials were obtained by ISTAT (Italian National Statistics Institute) at regional level (r), by year (t), for the 2000-2006 period.

Since the contractor's investment costs are not observable, as a measure of the cost variability (CVA), we construct a weighted average standard deviation by using COV relative to five ranges segmented as follows: [150,000 - 500,000 Euro), [500,000 - 1,000,000 Euro), [1,000,000 - 5,000,000 Euro), [5,000,000 - 15,000,000 Euro) and greater than 15,000,000 Euro. We justify this choice on the grounds that the CA's internal estimate of the project cost is revealed to all

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

[5] Similar evidence on delays is provided by Guccio *et al.* (2009), Decarolis and Palumbo (2011), and Coviello *et al.* (2011).

the bidding firms,[6] and that - for most work categories - the contractor firms' cost structure is the sum of an idiosyncratic component and a common component, i.e. some costs are relatively straightforward and depend more on a given firm's equipment and internal efficiency, while others are more volatile and their uncertainty affects all bidders (e.g. if the soil conditions at the site are not perfectly known until digging begins, or changes made to the contracted quantities of certain work items, or 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 variability of the prices represents a good proxy of the variability of the costs. In principle if the works in a given category are highly standardized, the winning firms should be prefectly homogeneous and the variability of the prices should be attributable exclusively to the variance of the common costs component.

Finally *CDA* indicates the days established in the contract for the completion of the works, *PRO* is a dummy variable indicating the awarding mechanism, distinguishing between "open" and "negotiated",[7] and X includes: a) the different types of CA awarding PPCs;[8] b) the different "types of works" awarded to the contractors, i.e. cultural goods, environmental protection, soil conservation, water resources, roads, railways, infrastructure and building construction.

We estimate equation (1) including time, province, CA and works fixed effects, and by clustering the standard errors at geographical level for the whole available sample.

Table 1 shows the standardized βs and the corresponding t-stat for each variable in four different regressions. Since a higher cost variability implies a higher option value to delay the investment, we expect a positive and significant β coefficient.[9] In detail, Column 1 shows the regression with fixed effects for

[6] This is called the engineers' cost estimate and is calculated 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) and it is used to establish a reserve value for a project and as a benchmark to assess the bids submitted and identify abnormally low bids (see Italian Governmental Decree n. 163/2006).

[7] In Italy, before the Governmental Decree n. 163/2006, PPCs were regulated by Law n. 109/1994 and Presidential Decree n. 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.

[8] Among the various types of Italian CA, we considered: Public Administrations, Regional Authorities, Territorial Association 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 administrator of public infrastructure and networks, and the Council Housing Board (IACP).

[9] In our regression, we found that *COV* and *CVA* were positive, and since they are both affected by the option value (even if *COV* is affected by the option value, *CVA* by its variabil-

province, year, type of public works and type of CA; Columns 2, 3 and 4 discard the fixed effects for province, type of works, CA, respectively, *ceteris paribus.* [10]

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

The empirical analysis seems consistent with our hypotheses. In all regressions the days of delay are positively correlated to *CVA* and *JUS* and are statistically significant.[11] This evidence supports the intuition, formalized in our model in Section 3 that suppliers are able to endogenize their decision about the timing of delivery taking advantage of the economic benefits deriving from both variability of the construction costs and the inefficiency of the judicial system.

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.[12] Thus while establishing a longer contract delivery time reduces the delays, high contract values and open procedures increase delays. Since the largest most complex contracts include many events (unexpected site conditions, bad weather, poor

ity), 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 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).

[10] The regressions in Table 1 and Table 2 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.

[11] Concerning the effect of the judicial system on time overruns in Italian PPCs, Coviello *et al.* (2011) found similar results using data on legal proceedings at provincial level.

[12] *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.

project planning, or late delivery of materials), that might delay the works, relaxing the contract time may prove more efficient than trying to describe the project more accurately (Bajari and Tadelis, 2001).[13]

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", in the lines and columns, respectively, in Table 2. As mentioned above, if, within a given works category, the firms awarded the contracts are homogeneous, the variance in the idiosyncratic cost component should be null, and the variability of the prices captures the variance of the common costs component. If this is the case, we expect CVA to be significant only in standardized work categories.[14]

For each sub-group, we checked for the Chow test[15] and estimated (1). Table 2 shows the level of the significance for CVA. The regressions show that the relation is significant (see last line in Table 2) for the following groups of works: roads, railways, infrastructure, buildings. We also found a strong significance in the low value ranges (for contracts worth 150,000 - 500,000 Euro or 500,000 - 1,000,000 Euro) and for the works relating to "cultural goods", "roads" and "railways" worth 1 to 5 million Euro, which accounted for 87% of the whole dataset (39,555 contracts of the 45,370 considered). Since lower-value works are generally more straightforward, or simple,[16] these results support the idea that cost variability is more important for standardized works, and becomes not 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 2 : Significance levels of CVA, for each type of works and value range.

[13] 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.

[14] 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.

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

[16] 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).

3 A model of strategic time overruns

Let us 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 1, $p = 1$. The PPC involves building a public infrastructure of specified dimensions with exogenous technical characteristics defined ex-ante. The contract includes the supplier's liability for completion on time, i.e. in the event of any delays, the supplier is liable to pay a set penalty, c, for each day of delay established as a percentage of the contract price.[17] Finally, to keep the model simple, we assume that the works can be built instantaneously. Under these assumptions, the Net Present Value (NPV) of the project or mark-up at time t, F_t, that complies with the contract delivery time is given by:[18]

$$F_t = 1 - C_t \ , \tag{2}$$

where C_t are the supplier's production costs.

If the production costs are stochastic, however, the variability of the costs 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 (2). In particular, assuming that the construction costs C_t evolve over time with a geometric Brownian motion:[19]

$$dC_t = \alpha C_t dt + \sigma C_t dz_t \ , \tag{3}$$

where $\alpha > 0$ and $\sigma > 0$, the supplier's opportunity to defer the execution time becomes analogous to a Put Option. Since suppliers cannot fully anticipate the costs and assuming, for the sake of analytical tractability, that they hold a

[17] We do not consider the case where the firm is awarded a premium (incentive) if it 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.

[18] The assumption that the works are built instantaneously can be relaxed without substantially altering the results. Let us assume that it takes a given "time-to-build" the works, but there is a maximum rate, m, at which the firm 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 pretty much as in the text.

[19] In (3), dz_t is the increment of a standard Brownian process with mean zero and variance dt (Dixit and Pindyck, 1994).

perpetual option, the *ex post* value of the contract is given by:[20]

$$P_t = \Phi_t - \pi \Lambda_t \tag{4}$$

where $\Phi_t \equiv E_t(e^{-r(\tau-t)})F_\tau$ and $\Lambda_t \equiv E_t\left[\int_t^\tau ce^{-r(s-t)}ds\right]$. In (4), Φ_t is the expected discounted net benefit obtainable by investing at costs $C_\tau < C_t$; Λ_t is the expected value of the penalty fee paid by the contractor; $\pi \in [0,1]$ is the probability of the firm paying this penalty; r is the discount rate and τ is the delivery time. Since $\Lambda_t \equiv \left[1 - E_t(e^{-r(\tau-t)})\right]\frac{c}{r}$, we can write (4) as:

$$P_t = E_t(e^{-r(\tau-t)})\left(F_\tau + \pi\frac{c}{r}\right) - \pi\frac{c}{r}. \tag{5}$$

Finally, since F_t is driven by a geometric Brownian motion too, the discount rate can be expressed as $E_t(e^{-r(\tau-t)}) = \left(\frac{F_t-1}{F_\tau-1}\right)^\beta$, where $\beta < 0$ is the negative root of the quadratic equation $\frac{1}{2}\sigma^2 x(x-1) + \alpha x - r = 0$. By substituting it into (5), we obtain the final expression for P_t as:[21]

$$P_t = \left(\frac{F_t - 1}{F_\tau - 1}\right)^\beta \left(F_\tau + \pi\frac{c}{r}\right) - \pi\frac{c}{r}. \tag{6}$$

Equation (6) 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 (6) with respect to F_τ in order to determine the optimal delay. The net benefit that will trigger the firm's investment is:[22]

$$F_\tau = 1 - \frac{\beta}{\beta - 1}(1 + \pi\frac{c}{r}) \tag{7}$$

Equation (7) 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), while if $F_\tau > F_t$, it is optimal to wait until the NPV equals F_τ.

Using (7), 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

[20] 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 contractor at 10% of p (see art. 145 Presidential Decree 270/2010). If the delays incur a penalty exceeding this treshold, the CA can terminate the contract and award the works to another contractor. In this case (4) 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 (4), but none of the results presented in this section are substantially affected.

[21] See Dixit *et al.* (1999).

[22] The first order condition is:

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

given by the value of c^* that makes the supplier indifferent between P_t and F_t, i.e.:

$$c^* = \frac{r}{\pi}\left(\frac{\beta-1}{\beta}C_t - 1\right) \tag{8}$$

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 firm's option value to delay increases. Further, since $d((\beta-1)/\beta)/d\sigma > 0$, we get the same result for increasing uncertainty.

To calibrate (8), we assume from here on that π may arise from at least two different sources: a) the law court's discretion and, b) the "quality" (i.e. 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 reasonably to cover the damages caused by the supplier's breach.[23] We model this discretion by assuming that π is a function of c with the properties that $\pi'(c) < 0$, $\pi(\underline{c}) = 1$ and $\lim_{c\to\infty}\pi(c) = 0$, where $\underline{c} \geq 0$ represents the minimum daily penalty (i.e. the time unit value) that the court considers "reasonable" as foreseen *ex ante* by the contractor.[24]

To allow for the influence of the "quality" of the judicial system on 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 contractor's expected penalty will be lower the longer it takes to reach a verdict in a civil trial. Based on these assumptions (8) becomes:

$$\pi(c^*)c^* - \frac{r}{\theta}\left(\frac{\beta-1}{\beta}C_t - 1\right) = 0, \qquad for \;\; c^* \geq \underline{c}. \tag{9}$$

4 Numerical study

To illustrate the properties of (9) with reference to the Italian case, we provide some numerical solutions for c^* (Tables 4, 5, 6, 7). We further specify different values for θ according to the data on the average length of ordinary civil trials in different Italian regions (Table 1) and compare Northern and Central Italy with Southern Italy (Figures 1, 2).

[23] This discretionality of the court is commonly referred to as the "liquidated damages principle". Delay in delivering the contracted investment should be referred to a specific case of the firm'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.* (2004, Ch. 4, pp. 85-86); for an analysis of the economic incentives pertaining to it, see Anderlini *et al.* (2007).

[24] 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.

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 values of 0.03% and 0.1%, which are respectively the lower and upper limits of the penalty in PPCs as set by the Italian legislation[25], while the elasticity η takes two different values, $\eta = 0.3$ and $\eta = 0.5$, respectively.

Based on the above assumptions, equation (9) becomes:

$$c^* = \max\left\{ \underline{c} \ \ , \ \ \frac{\left[r/\theta\left(\frac{\beta-1}{\beta}C_t - 1\right)\right]^{1/1-\eta}}{(\underline{c})^{\eta/1-\eta}} \right\}. \tag{10}$$

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[26] is $r = 0.05$; the investment costs amount to $C_t = 0.7, 0.8, 0.9$ [27]; the drift is $\alpha = 0.03$[28] 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 (Table 1).

Tables 4 and 5 show the value of c^* for $\underline{c} = 0.03\%$, with $\eta = 0.3$ and $\eta = 0.5$ respectively, while Tables 6 and 7 show the values of c^* for $\underline{c} = 0.1\%$ with $\eta = 0.3$ and $\eta = 0.5$ respectively.

The 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. In addition, it is evident that c^* is highly sensitive to $\underline{c}$. Specifically, when the value of the penalty that the court considers "reasonable" is $\underline{c} = 0.03\%$, Tables 4 and 5 show that c^* always exceeds $\underline{c}$ except for very low values of σ. In contrast, when $\underline{c} = 0.1\%$ (Tables 6 and 7), c^* is only higher than 0.1% for high values of σ.

[25] Italian legislation sets a 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 n. 163/2006 and Presidential Decree n. 270/2010. See also art. 145 Presidential Decree n. 270/2010.

[26] 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, this ranges between 8% and 12%, possibly dropping to 5% for projects undertaken in the south of the country (see Pennisi and Scandizzo, 2003).

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

[28] $\alpha = 2.5\% - 3\%$ 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.

α=0,025		c*			
		r=5%			
		σ=20%	σ=30%	σ=40%	σ=50%
C_t	0,9	0,03%	0,0911%	0,2028%	0,3737%
	0,8	0,03%	0,0622%	0,1523%	0,2927%
	0,7	0,03%	0,0369%	0,1064%	0,2180%

Table 4: c^* for different values of C_t and σ, $\underline{c} = 0.03\%$, $\theta = 1/3, \alpha = 0.03$, $r = 5\%$, $\eta = 0.3$ 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	0,0560%	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 5: 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%	0,1210%	0,2231%
	0,8	0,1%	0,1%	0,1%	0,1747%
	0,7	0,1%	0,1%	0,1%	0,1301%

Table 6: c^* for different values of C_t and σ, $\underline{c} = 0.1\%$, $\theta = 1/3, \alpha = 0.03$, $r = 5\%$, $\eta = 0.3$ 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 7: 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 daily 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 contractor firm's value to delay (i.e. the supplier's willingness to pay for postponing the execution time), corresponds exactly to $\underline{c}$. So, 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 enforcebility of its penalty clause.[29]

Conversely, if the court reduces the amount of the daily 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 firm gains $c^* - \underline{c}$.

Finally, to highlight the effects of the "quality" of the judicial system on c^*, we set $\alpha = 0$[30] and assume $\theta = 0.5$ for Northern and Central Italy (NCI henceforth), and $\theta = 0.25$ for Southern Italy (SI henceforth), respectively. These parameters imply that the average time taken to complete ordinary civil trials is 2 years for NCI and 4 years for SI.

Figures 1 and 2 below illustrate the results of the simulations when $\underline{c} = 0.1\%$, $\alpha = 0$, $r = 5\%$ and $\eta = 0.3, 0.5$.

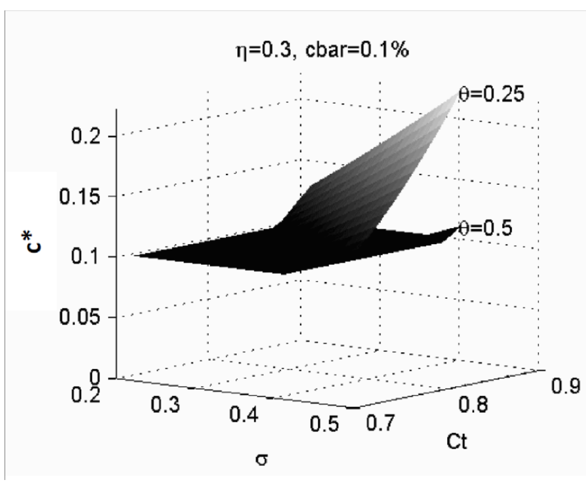

Figure 1: c^* expressed as percentage and in terms of days for $\underline{c} = 0.1\%, \eta = 0.3$, with respect to increasing σ and C_t

[29] 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 .

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

Taking a look at Figures 1 and 2, it is easy to see that c^*decreases with 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 with increasing values of C_t and σ. Note, for example, that when $\eta = 0.3, 0.5$, $\underline{c} = 0.1\%$, $\alpha = 0$, $r = 5\%$, $C_t = 0.9$ and $\sigma = 40\%$, the option value to delay is twice as high in SI as in NCI. In particular when $\eta = 0.5$ then $c^* = 0.29\%$ in NCI, and $c^* = 0.58\%$ in SI. These findings are confirmed, *ceteris paribus*, for $\eta = 0.3$ where $c^* = 0.11\%$ in NCI while $c^* = 0.22\%$ in SI.

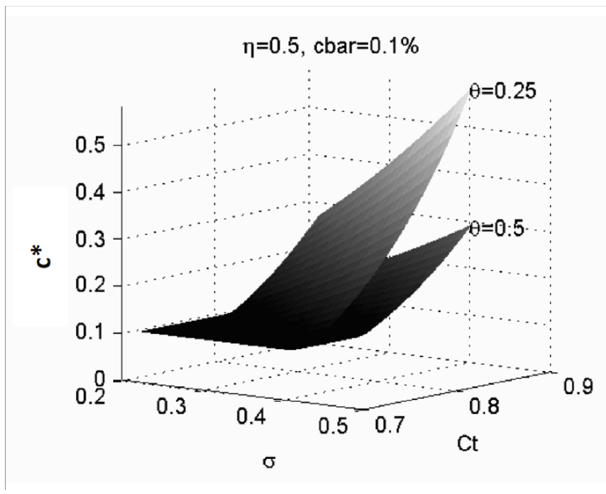

Figure 2: c^* expressed as a percentage and in terms of days for $\underline{c} = 0.1\%, \eta = 0.5$, with respect to increasing σ and C_t

5 Conclusion

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 is a key issue for investigation. Uncertainty in the estimated investment costs can give rise to significant risks and opportunities, which may prompt suppliers to adopt an opportunistic behavior, such as time overruns.

Opportunistic behavior can be interpreted in this setting an offer strategy by the contracting firm: 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. This investment timing flexibility has an economic value that, optimally exercised, may increase the value of the contract for the supplier.

In this paper, we investigate whether, irrespective of any penalty clause included in the procurement contract, the perception of uncertainty over investment costs and the flexibility to defer the works create an incentive to adopt an opportunistic behavior and thus generate strategic time overruns. Following the real option approach, we calculate the maximum penalty per day that suppliers are willing to pay to delay the execution of the works and infringe the contract provisions on the delivery date. Our model takes into account both the discretion of the law courts in enforcing contractual clauses and the quality of the judicial system.

The model's predictions are supported by calibrations performed on the Italian case. We show that: the greater the uncertainty over the construction costs, the higher the maximum amount per day, c^*, that the supplier will be willing to pay to defer the investment (i.e. the higher the option value of delaying the works and, as a consequence, the greater the incentive to delay). We also show that the option value to delay is very sensitive to the "quality" of the judicial system and to the discretion of the court in reducing or even not enforcing any penalties incurred. As the "quality" 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 PPCs awarded and completed in Southern Italy than for those located 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 dimensions of the contracted works increases.

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