Understanding the procurement performance of local governments: A duration analysis of public works

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Introduction and Previous literature

- The most common efficiency markers (usual response variables in empirical studies) in the procurement of public works are cost and time overruns (delays).
- Much theoretical and empirical literature has focussed on cost overruns, while a few contributions have analysed delays (Lewis and Bajari, 2011; Guccio et al., 2014).
- The social price of a delay can go beyond what is actually paid for the contract, in that a delay involves other costs, inflicts negative externalities and entails the dissatisfaction (or postpones the satisfaction) of collective needs (Lewis and Bajari, 2011).
- Moreover, although many causes of public works procurement inefficiencies have been investigated (contract incompleteness, poor institutional environments, court inefficiencies, messy normative frameworks, corruption), two relevant aspects have received very little attention so far:
  - buyers' lack of technical expertise to frame or follow up projects
  - tight constraints on public budgets
- The latter two aspects are generally regarded as something that sees peripheral procurement authorities, namely municipalities, suffer from a disadvantaged position relative to higher government levels (e.g. Brown and Potoski, 2003a; Guccio et al., 2014a; Ambrosanio et al., 2016). ▸ Italy

Contribution and data

We focus on the influence that **local authorities (municipalities) characteristics** may play on the **execution time performance** of their procurement.
In particular, we pay special attention to the role of municipalities' **procurement experience** in preventing delays or in reducing their duration, as well as to the influence on these delays exerted by the presence of tight **constraints on public budgets**.

- We investigate these aspects using a rich administrative dataset of public works implemented by the municipalities of Tuscany from 2012 to 2015 (SIMOG and SITAT databases).
- The sample employed in the current analysis consists of the 1,310 public works awarded by Tuscan municipalities in the period January 2012 – April 2015. The total number of municipalities (buyers) included in the sample is 196.
- Tuscany:
  - the composition of Tuscan and Italian public works is roughly the same both in terms of financial size and sectoral mix
  - the total amount of public works is that of an average Italian region.
  - interesting variability at the level of works carried out by municipalities (share of works and work value managed by municipalities above the national average)

The empirical strategy

The problem that underlies our empirical analysis can be presented as follows:

- The total execution times of each public work can be split into two time intervals. In the first time interval, the work's execution is still on time (duration <= contractual duration). If completed during this first time interval, the work makes the infrastructure ready in due time and exits the population under scrutiny. If, instead, the work exceeds its expected (contractual) duration, the work is a delayed one.
- The execution times of delayed works are right-censored, which occurs in 39.5% of cases. ▸ Duration Under these circumstances, duration models are the appropriate tool to analyse the data (e.g. Box-Steffensmeier and Jones, 2004).
- A **split-population model** is the appropriate way to address the issues above (Schmidt and Witte, 1989). It is a two-part (mixture) model in which the **probability of the occurrence of a delay** and the **delay duration** are separately accounted for, entering the model in multiplicative fashion. Both the probability of delay and the delay duration depend (separately) on the work's characteristics.

The model

- $D = \{0, 1\}$ is the binary variable that indicates if a work is a delayed one
- T denotes the positive random variable representing time to work completion for a delayed work
- $h_w(t)$ is the hazard of completion of each given work
- x_w is a vector of explanatory variables

We can write our model as follows:

$$h_w(t) = Pr(D_w = 1|x_w) \cdot h_w^*(t|D_w = 1, x_w^*)$$

where h_w^* is the conditional hazard that can exist only when $D = 1$ or, equivalently, when $T > 0$.

1. We estimate the probability of delay (first part) by means of a logit model
2. As for the second part, we need a duration model. A valid option is the Cox model, where the hazard of completion of each given delayed work h_w^* is a function of the baseline hazard function h_b^* and the vector of explanatory variables x_w^*:

$$h_w^*(t) = h_b^*(t) \cdot e^{\beta^* x_w^*}$$

The duration model for delayed works

However, if two delayed works are characterised by different degrees of complexity that result, for example, into different expected durations, it makes little sense to assume that the duration of the delay can be represented by means of a hazard function that is common to the two groups (proportionality assumption of the Cox Model).

We thus use a **stratified Cox model**, where the hazard of completion of each delayed work, $h^*_w(t)$, is a function of a **group-specific baseline hazard function** $h^*_{b,g}(t)$ and of the vector of explanatory variables:

$$h^*_w(t) = h^*_{b,g}(t) \cdot e^{\beta^* x^*_w}$$

We define the strata of expected durations after a careful inspection of the hazard functions that are obtained under different grouping scenarios. ▸ Strata

By exponentiating the coefficients, we obtain hazard ratios:

$$HR_X = h^*_{X=1}(t)/h^*_{X=0}(t) = e^{\beta^*_X}$$

which represent the proportionate increase or reduction in risk occurring when x^*_w takes values different from the baseline layout of explanatory variables.

Model specification

1. Explanatory variables defined at the work level ▸ Stats
   - Contractual duration (stratification variable in the duration model)
   - Work value
   - Auction format (Decarolis et al. (2010)).
   - Public work's sector
   - Public work's type (binary variable: 1 if the work consists of the creation of a new infrastructure, 0 if it is rather aimed at its maintenance or restoration.)
2. Explanatory variables defined at the municipality level ▸ Stats
   - Resident population
   - **Delayed payments** (bynary variable based on variation of capital expenditure arrears: 1 if municipality's average yearly percent variation of capital expenditure arrears (2012-2015) is positive)
3. Explanatory variable related to works in a specific municipality ▸ Stats

   Municipality experience: by looking at the amount and at the sectors of public works procured during the time period 2009-2011, we classify works into three classes: works falling under municipalities with no experience at all (inexperienced); works falling under municipalities that have previous experience but only in a different sector of works (unspecialised); works under municipalities that have previous experience in the same sector of works (specialised).

Table 3. Coefficient estimates

		(1) Logit model for the probability of delay (all works)		(2) Cox model for the duration of delay (delayed works only)		(3) Cox model for the works' total duration (all works)	
		Coeff.	S.E.	Coeff.	S.E.	Coeff.	S.E.
Exp.duration:	3- (B)	0	-	Stratification variable		Stratification variable	
	3-4	0.266	0.176				
	4-7	0.610**	0.255				
	7+	0.528**	0.250				
Work value (centred, B=0)		0.009	0.009	-0.001	0.002	-0.004**	0.002
Maintenance works (B)		0	-	0	-	0	-
New infrastructure		0.422***	0.152	-0.001	0.115	-0.148*	0.087
Sector:	Buildings	0.610***	0.179	-0.063	(0.110)	-0.269**	0.109
	Roads (B)	0	-	0	-	0	-
	Environment	0.602**	0.254	-0.087	0.154	-0.243**	0.120
	Culture	0.831***	0.286	-0.149	0.158	-0.390***	0.137
	Other	0.240	0.272	-0.257	0.168	-0.225	0.142
Awarding procedure:	Average-bid auction	-0.268	0.396	0.109	0.234	0.174	0.159
	First-price auction	-0.311	0.373	-0.369	0.365	-0.118	0.205
	Scoring-rule auction	-0.528	0.484	-0.137	0.250	0.120	0.212
	Negotiation (B)	0	-	0	-	0	-
	Piecework contract	-0.174	0.219	-0.010	0.276	-0.006	0.168
Population:	< 2,000 (B)	0	-	0	-	0	-
	2,000-5,000	0.296	0.325	0.103	0.248	-0.041	0.193
	5,000-15,000	0.311	0.296	0.382	0.240	0.099	0.185
	15,000-50,000	-0.102	0.305	0.318	0.251	0.194	0.197
	>50,000	-0.004	0.342	-0.010	0.231	-0.010	0.201
Inexperienced (B)		0	-	0	-	0	-
Unspecialised		-0.598*	0.351	0.542*	0.324	0.525**	0.242
Specialised		-0.754**	0.332	0.690**	0.314	0.669***	0.231
Does not postpone payments (B)		0	-	0	-	0	-
Postpones payments		0.778***	0.272	-0.580***	0.154	-0.513***	0.134
Does not postpone# Work value (B)		0	-	0	-	0	-
Postpones # Work value		0.038***	0.013	-0.009	0.006	-0.014**	0.00561
Constant		0.910*	0.520				
Observations		1,310		856		1,310	
Log-likelihood		-789.1		-2,433.8		-4,963.7	

Municipalities are 196 in models (1) and (3), 181 in model (2). (B)indicates the baseline value /category of each variable. The coefficient on Work value refers to a 10,000 Euros increase in the value. Standard errors are cluster-robust at the level of municipality. Statistical significance: $^{*}p<0.10$, $^{**}p<0.05$, $^{***}p<0.01$

Probability of delay and Hazard Ratios

Suppose a very small municipality with less than 2,000 residents contracts out, through negotiation, a work of average value whose expected duration exceeds 7 months...

	Experience			*Postpones payments vs Does not postpone payments*
	Specialised vs Inexperienced	*Unpecialised vs Inexperienced*	*Specialised vs Unspecialised*	
Differential probability of delay (from Logit Model):				
Whatever sector or type	-0.133*** (0.055)	-0.102* (0.060)	-0.031 (0.042)	0.133*** (0.042)
Road maintenance	-0.165** (0.069)	-0.128* (0.072)	-0.037 (0.049)	0.169*** (0.057)
Road construction	-0.138** (0.058)	-0.105 * (0.060)	-0.033 (0.043)	0.141*** (0.050)
Heritage restoration	-0.109** (0.050)	-0.082* (0.048)	-0.027 (0.036)	0.112** (0.045)
Hazard ratio(from Cox Model for delay duration)	1.994** (0.626)	1.720** (0.557)	1.159 (0.150)	0.560*** (0.086)
Hazard ratio(from Cox Model for total work's duration)	1.952*** (0.452)	1.691** (0.408)	1.155 (0.115)	0.598*** (0.080)

Standard errors are cluster-robust at the level of municipality. Statistical significance: $^{*}p<0.10$, $^{**}p<0.05$, $^{***}p<0.01$

Conclusions

- This article has studied the timing of execution of public works procured by municipalities, aimed at the creation and maintenance of local infrastructures.
- We have adopted a two-part mixture model in order to account both for the probability od delay and the duration of delays. In order not to limit the analysis to concluded works we have used survival analysis techniques to investigate delay durations.
- We have approached the issues regarding municipality-level procurement in an explicit fashion taking into account both technical/organisational and financial characteristics of municipalities
- We find that:
  - insufficient procurement experience is associated with a higher probability of incurring delays and with substantially longer delay durations
  - municipalities that postpone payments in response to budget constraints are more likely to face delays and longer work durations.
- Possible remedies range from the reinforcement of the competencies of local procuring authorities by means of resource pooling, to the centralisation of procurement into the hands of specialised technical bodies or higher government levels.

Italian public works by procuring authority

Table 1 – Number, total and average value of public works with a value over 40,000 Euros awarded in Italy in 2012, by procuring authority

	Number		Amount		Average value
	N	%	Million Euros	%	Thousand Euros
Central government	1,212	6%	547	5%	451.3
Sub-central governments	10,575	53%	2,942.3	29%	278.2
Regions	636	3%	252.8	3%	397.5
Provinces	1657	8%	615.3	6%	371.3
Municipalities	8,282	42%	2,074.2	20%	250.4
Universities	323	2%	121	1%	374.6
Local health units	582	3%	280	3%	481.1
IMCs	4,621	23%	4,997	48%	1,081.4
Other	2,506	13%	1,416.8	14%	565.4
Total	19,819	100%	10,304.2	100%	519.9

Source: Authors' elaboration of data reported in AVCP (2013).

Back

Duration and delay duration of works

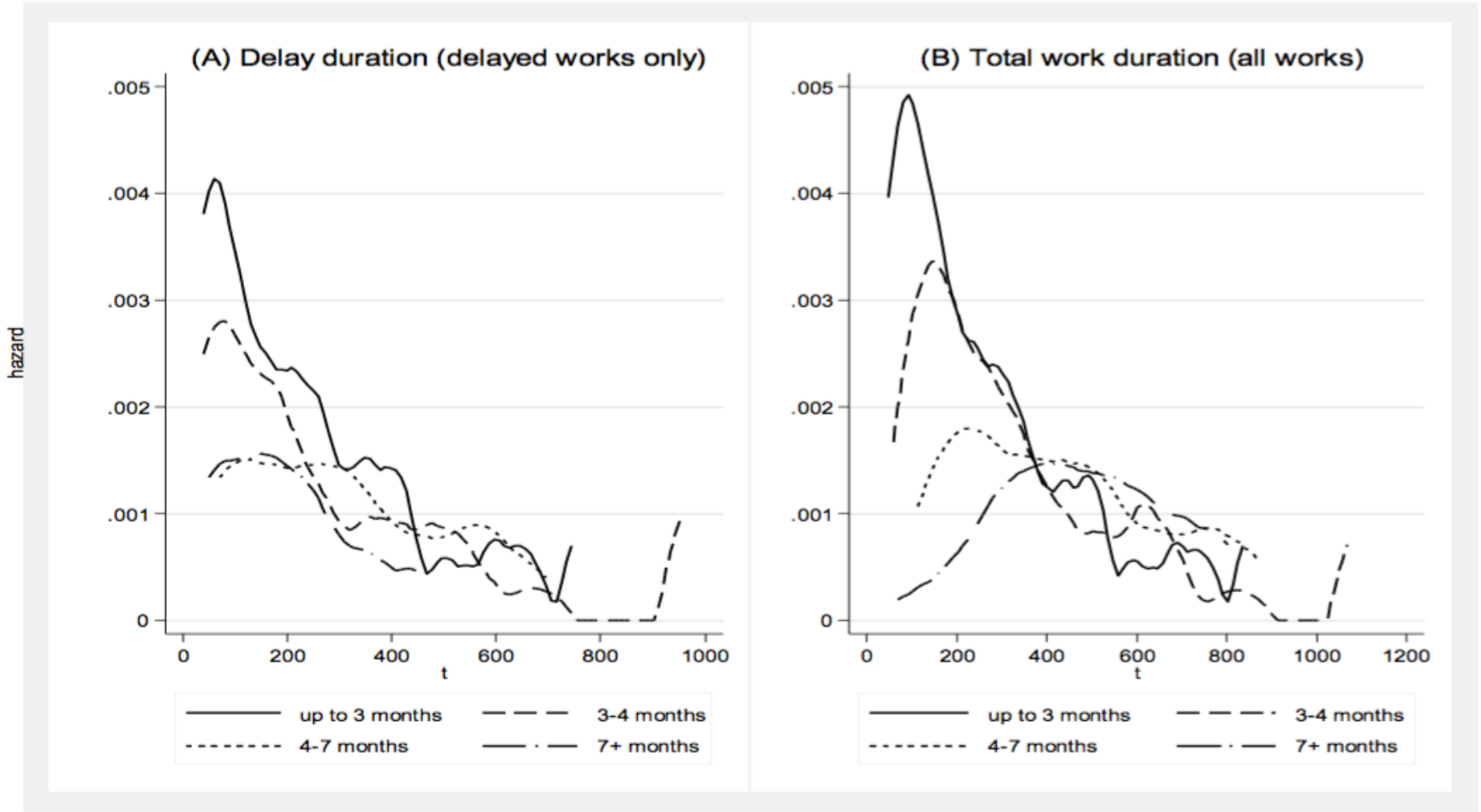
Table 2. Descriptive statistics at the work and at the municipality levels. Proportion or Mean (S.D)

	All		On-time	Delayed
	At the work level	At the municipality level		
Variables related to the duration of works and delays				
Completed during observation period (1/0)	0.742	-	1	0.605
Average duration of completed works (Days)	213 (170)	-	115 (94)	299 (175)
Average duration of all works (Days)	310 (271)	-	115 (94)	414 (278)
Delayed works (D = 1)	0.653		0	1
Average delay of completed but delayed works (Days)	-	-	-	132 (136)
Average delay of all delayed works (Days)	-	-	-	224 (234)
Observations	1,310	196	454	856

Back

Baseline hazard functions

Figure 1. Smoothed baseline hazard functions for different strata of expected work duration



Back

Descriptive statistics - variables defined at the work level

Table 2. Descriptive statistics at the work and at the municipality levels. Proportion or Mean (S.D)

	All		On-time	Delayed
	At the work level	At the municipality level		
Explanatory variables defined at the work level				
Contractual duration (Months)				
<3	0.279	-	0.363	0.235
3-4	0.310	-	0.322	0.304
4-7	0.192	-	0.148	0.216
>7	0.218	-	0.167	0.245
Work value (Euros)	280,261 (638,128)	-	176,583 (510,618)	336,167 (690,257)
Awarding procedure				
First –price auction	0.027	-	0.029	0.026
Average-bid auction	0.041	-	0.033	0.046
Scoring-rule auction	0.049	-	0.033	0.057
Negotiation	0.765	-	0.762	0.766
Piecework contract	0.118	-	0.143	0.105
New infrastructure (1/0)	0.289	-	0.238	0.316
Sector				
buildings	0.331	-	0.293	0.352
roads	0.377	-	0.460	0.333
environmental protection	0.074	-	0.055	0.084
culture	0.089	-	0.055	0.108
other	0.128	-	0.137	0.124
Observations	1,310	196	454	856

Back

Descriptive statistics - variables defined at the municipality level

Table 2. Descriptive statistics at the work and at the municipality levels. Proportion or Mean (S.D)

	All		On-time	Delayed
	At the work level	At the municipality level		
Explanatory variables defined at the municipality level				
Resident population in 2011				
< 2,000	0.062	0.184	0.053	0.067
2,000-5,000	0.131	0.240	0.115	0.140
5,000-15,000	0.263	0.342	0.229	0.280
15,000-50,000	0.234	0.174	0.278	0.210
>50,000	0.311	0.061	0.326	0.303
Delayed payments (based on variations of arrears) (1/0)	0.119	0.179	0.084	0.138
Observations	1,310	196	454	856

Back

Descriptive statistics - experience

Table 2. Descriptive statistics at the work and at the municipality levels. Proportion or Mean (S.D)

	All		On-time	Delayed
	At the work level	At the municipality level		
Explanatory variable related to works in a specific municipality				
Experience of the municipality in the specific sector of work				
inexperienced	0.037	-	0.022	0.046
unspecialised	0.169	-	0.145	0.181
specialised	0.794	-	0.833	0.773
Observations	1,310	196	454	856

Back