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

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Abstract

Public works often suffer from excessively long durations and time escalations. The underlying reasons also lie in the procuring authority's ability to manage the process. Using micro-level data on the works recently procured by the municipalities of a large Italian region, we analyse delay incurrence and the subsequent time-to-completion of works. For this purpose, we rely on a split-population duration model. In particular, we investigate if appropriate levels of expertise and experience – which are often believed to be lacking in municipalities – have a role in speeding up works' executions. Our findings show that the lack of experience is actually an issue that requires appropriate remedies, in that it brings to higher delay probability and longer delay durations. The same applies to municipalities that resort to late payments in response to budget constraints.

Keywords: infrastructure provision, municipalities, delays, split-population models

1 Introduction

It is usually by contracting out works that public authorities provide for the creation and maintenance of the majority of infrastructures. As a whole, the purchase of works, services or supplies by public authorities accounts for a sizeable share of economic activity and is increasingly regarded as an essential tool of economic policy (e.g. Uyarra and Flanagan, 2010; Pickernell et al., 2011; Loader, 2013). As such, it receives remarkable attention from scholars in different areas of economics, public administration and policy management.

As a starting point, it is worth recalling that two problematic – sometimes interplaying – issues may arise after a project for the creation or the maintenance of infrastructure is launched: cost and time escalations. Generally speaking, the procurement of public works relies on contracts that are subject to information asymmetries (the executing company is more familiar with its production costs than the public authority and the latter can hardly observe the real effort of the firm over the course of contract execution) and contractual incompleteness (it is impossible to foresee and regulate in the contract any possible problem or hazard that might arise during its enforcement) (e.g. Saussier and Tirole, 2015). Under these circumstances, a public authority that is benevolently willing to strike a balance between cost savings and value for money can exert only limited control on the different stages of the process. Therefore, it can be hard to prevent the occurrence of additional costs, renegotiations or delays when these are the price to pay in order to ensure the final delivery of the infrastructure to the community. Of course, it has been emphasised that problems can be much worse if the public authority is not pursuing the public interest, or if it is captive of lobbies or corrupted (Flyvbjerg, 2007; Piga, 2011). Even ruling out these complications, cost and time escalations are likely to arise, which implies higher social costs and/or lower social benefits (Tirole, 1986; Flyvbjerg et al., 2002; Ganuza, 2007; Siemiatycki, 2009; Lewis and Bajari, 2011; Guccio et al., 2012b and 2014b). Whereas the price of cost escalations basically consists of a higher monetary burden on the public authority's and on the taxpayers' shoulders, 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). Therefore, it is important to understand what brings to delays in public works and what makes these delays as short as possible, a goal that has been pursued by previous empirical research only in a limited number of cases (e.g. Guccio et al., 2014a) and that will lie at the core of our analysis.

The previous empirical economic literature on public works has mostly focussed on the relationship between the awarding stage (auction design) and the ex-post procurement performance. One issue that still remains in the shade relates to the buyers' characteristics and the influence that they may play on procurement performance. This article starts to address this issue, which constitutes its main contribution to the literature. In fact, in addition to the aspects already analysed in the previous empirical studies, it pays special attention to the role of the public authority's 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. 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). Therefore, the focus of our analysis is placed on municipalities in order to understand to which extent these arguments actually hold. In our view, this kind of analysis can be interesting beyond the rather specialised literature devoted to public procurement, in that it offers broader insights on what can make local administrations more effective in providing their communities with infrastructure and other public goods.

We investigate these aspects using a rich administrative dataset of public works implemented by the municipalities of a large Italian region (Tuscany) from 2012 to 2015. As many other areas in Europe, this region is characterised by low corruption and decent quality of government and institutions, which makes the issues raised in the article interesting well beyond local or Italian boundaries (Golden and Picci, 2005; Charron et al., 2013; Nifo and Vecchione, 2015; Rodríguez-Pose and Garcilazo, 2015).

An additional element of originality of our approach lies in the way the empirical analysis is framed to attain the research objective of explaining delays. In particular, we are interested in deconstructing the analysis of work's duration into two specific sub-issues: i) what factors affect the probability of occurrence of a delay; ii) what factors affect the duration of these delays, if any. We assess these elements by means of a two-part, split-population duration model (Schmidt and Witte, 1989). To our knowledge, this is the first contribution that adopts an approach based on survival analysis to the study of delays in the provision of public infrastructures.

Results prove that experience helps municipalities manage their procured works, both preventing delays from occurring and reducing their duration. They also show that works falling under municipalities with strict spending restrictions, i.e. those who postpone payments, face a higher probability of delay and longer delay durations.

The article proceeds as follows. Section 2 sets out the conceptual framework of the analysis, while Section 3 briefly portrays the Italian institutional context in the area of public work procurement and introduces the data under scrutiny and their sources. Section 4 discusses the modelling approach chosen for the empirical analysis, while Section 5 illustrates which variables are inserted in the model and how. Section 6 presents and discusses the results of our investigation. Section 7 concludes.

2 The procurement of public works in local governments

The life of a procurement contract consists of different stages, which go from the selection of the company to which the project will be outsourced to the execution and closure of the related works. Each stage requires the public authority to mobilise specific expertise. As stressed by Saussier and Tirole (2015), ability and expertise may lack for a number of reasons that hamper experiential learning and the creation of an institutional memory within the public authority, including a personnel policy that – and this is perhaps more likely to happen when the procurer is a small territorial authority – not always encourages and rewards professional qualification. All the more reason to consider the accumulation of experience and know-how with respect to all contract stages as a key point in procurement management (Brown et al., 2006).

A first important issue that needs to be managed refers to the choice or the most appropriate way to outsource the work. On this point, the empirical literature has extensively focussed on the choice of the auction format and on the resulting selection of contractors by means of more or less competitive procedures. These procedures have attracted remarkable attention for the role they can play in explaining the final cost and the time-to-completion of public works.

Based on economic theory, one could deem competitive bidding procedures, namely auctions, more desirable than more opaque negotiations. In practice, things are less straightforward than in theory. On the one hand, the savings initially accomplished with competitive tendering are often eroded or nullified by subsequent renegotiations that entail adaptation costs (Guccio et al., 2012a; Bucciol et al., 2013; Decarolis and Palumbo, 2015; Saussier and Tirole, 2015). Indeed, a careful screening of proposals, as happens with selection procedures that require an assessment of the value for money and favour the most economically advantageous bid, is likely to limit subsequent adaptations, but is also likely to imply longer times to award the contract (Decarolis, 2014). On the other hand, negotiations ensure a faster signature of the contract, especially with small works; moreover, as stressed by Bajari et al. (2009), they may outperform competitive auctions in a number of other specific situations, including that of complex projects whose design requires some interaction between the company and the public authority (see also Brown et al., 2016).

Compared to the abundance of studies regarding selection, the stages of contract execution have received only modest attention. Here, the public authority is called to monitor and control the contract's enforcement until the work's completion (Brown and Potoski, 2003b; Fernandez, 2009). In fact, it can be sensibly maintained that the public authority's levels of ability, expertise and experience that are supposed to ease selection stages can be no less important during execution, where several criticalities might require to be addressed so as to, for example, prevent a delay or reduce its duration. Unfortunately, the empirical research on the topic is often hampered by the lack of those data that would be necessary to assess the intensity and the quality of the public authority's management and monitoring effort.

In addition to know how and effort, other characteristics of the procurement agency can affect the duration of work executions. It is the case of budget constraints, which can be particularly challenging for those authorities, such as municipalities, which can rely only on limited taxing powers and, therefore, cannot raise tax revenues enough to finance all their investment decisions. As highlighted in Checherita-Westphal et al. (2015), one undesirable implication of the current fiscal austerity, for example in the Euro area, is that public authorities delay their payments, especially those related to the purchase of services, supplies or works. Now, when due payments are postponed it is not unlikely that the works' execution also slows down, especially for projects that require interim payments based on actual work progress in order to proceed further.

The infrastructures to which public works refer are usually location-specific public goods, as they serve particular areas or communities (Bird, 1995). This results in the fact that different levels of government may be involved in their provision, often depending on how broad is the area or the community that is supposed to take advantage of the infrastructure itself. In practice, infrastructure investment is widely decentralised to regional or local authorities in most developed countries (Estache and Sinha, 1995; Kappeler et al., 2013). This circumstance fuels an everlasting debate over the costs and benefits of decentralisation (Dimitri et al., 2006), a debate that relies more on theoretical arguments than on empirical evidence, with some authors casting several doubts on the ability of peripheral authorities to achieve satisfactory procurement performances due to moderate specialisation and professionalism, weak negotiation power, and so on. This is, however, a thorny issue. Even if municipalities were entitled to decide what works need to be done, the centralisation of procurement procedures, e.g. the creation of joint service centres at the level of regions or intercommunalities, could eventually limit accountability towards local communities, increase red tape for minor works and result in a loss of flexibility (Saussier and Tirole, 2015).As for the limited empirical evidence on this point, Guccio et al. (2014a) have recently reported that local governments incur longer work delays than their central counterparts.[1] Our work adds to the latter line of empirical research by examining some of the reasons why this could occur. As previously said, our focus comprises several possible delay factors, including some that were not accounted for in previous studies.

3 Institutional framework and data

The Italian public procurement system is characterised by a large number of buyers acting at different institutional levels: ministries, regions, provinces, municipalities, other public bodies such as universities, local health units, government-owned companies and infrastructure management companies/concessionaries (IMCs). A recent report of the Italian public procurement's authority (AVCP, 2013) shows that the total number of works with a value over 40,000 Euros awarded in the country was 19,819, corresponding to a total amount of 10.3 billion Euros. The sub-central governments, and in particular municipalities among them, accounted for the highest share of the overall works but for a comparatively lower share of the total value. This results in a low average value of the works contracted out by Italian municipalities that is, for instance, half the value of the central government's one, and four times lower than the IMCs one.[2]

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).

Despite the considerable differences in the average value of the works managed by municipalities, central government and IMCs, the most recent reports on the state of the Italian procurement system highlight that the problem of too long time to conclude public works seems to be common to all types of works and procurers (DPS, 2014).[3] The fact that peripheral authorities manage smaller projects that nevertheless incur delays could suggest that they face more difficulties in managing their projects than higher government levels.

Moreover, as Guccio et al. (2014a) point out, any difference in the execution timing of public works

[1]Some more empirical evidence is available with respect to areas of procurement other than public works, such as the purchase of supplies, where the benefits of centralisation are found to have opposite signs in different studies (Bandiera et al., 2009; Baldi e Vannoni, 2015).

[2]Infrastructure management companies are different from other procurer types since they are not tied to an administrative/territorial context and typically manage works (railways, airports, ports, etc.) characterised by a high level of complexity.

[3]Note that 77% circa of Italian public works, tendered and completed in the period 2000-2007, present delays with respect to contracted time of completion (AVCP, 2009; Decarolis and Palumbo, 2011).

across Italian levels of government cannot be ascribed to normative issues. In fact, there exist no differences in the categories of works that central and sub-central procurers can put out to tender and manage and, moreover, both levels of government must follow an identical set of rules in the execution phase, entirely set out by the national Parliament.[4] If so, any difference in execution timing can be explained by assessing other factors, including those recalled in the Introduction of this article.

In spite of the fact that each procurer is responsible for its own works, the central authority on public procurement (from 2014 National Anti-Corruption Authority, ANAC) is called to collect data on all public works in the country. The resulting dataset (referred to as SIMOG – Sistema Informativo Monitoraggio Gare) should be the major information source for all scholars interested in public procurement in Italy, and ours among the others. Our analysis is, in fact, based on these data. In particular, our analysis relies on the available dataset of works awarded in the region of Tuscany in last years. In order to improve the extent and the quality of information at our disposal, we considered also the SITAT (Sistema Informativo Telematico Appalti Toscana) dataset from the Observatory on public contracts of the Tuscany Region.

Tuscany has several characteristics that make it quite a typical area in the country for what concerns public works. First, the composition of Tuscan and Italian public works is roughly the same both in terms of financial size and sectoral mix. Second, the total amount of public works is that of an average Italian region.

Moreover, as to the relevance of the municipal action, we note that the share of works (54% in the period 2012-2015) and work value (37%) managed by municipalities is above the national average, with a comparatively lower share of works managed by the central government and IMCs. This circumstance provides us with interesting variability at the level of works carried out by municipalities.

Each record of the dataset (public work) corresponds to a single lot, which can represent a project or only a part of a multi-lot project. 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.

The dataset includes very detailed information on the various steps of the works' life starting from the project phase on to the tender procedures and execution and final accounting. Even if our interest lies in the execution phase of the public works, we also draw information relative to previous stages (such as those concerning the tender procedure and the award criterion) which - according to a very common view in the literature - may contribute to explain different execution time performances.

4 A split-population duration analysis

The problem that underlies our empirical analysis can be presented as follows. The total execution times of each work w can be split into two time intervals. In the first time interval, the work's execution is still on time, i.e. the count of the days does not exceed the number of days that the work is expected to last based on the contract. During this first time interval, the work can be completed or not. If completed, the work makes the infrastructure ready in due time and exits the population under scrutiny. If, instead, the work exceeds its expected duration, the delivery of the infrastructure to the community will be delayed.

A split-population model is the appropriate way to address the issues above (Schmidt and Witte, 1989). [5] It is a two-part duration model in which the probability of the occurrence of a delay is less

[4]There can be some differences in the regulation at local level (Decarolis and Giorgiantonio, 2015) but these differences, if any, only affect the tendering stage and not the subsequent stages of the work's life.

[5] The extension of the Schmidt and Witte's split-population approach to the case where data are right-censored was put forward by Swaim and Podgursky (1994).

than one and in which both the probability of delay and the delay duration depend (separately) on the work's characteristics.

It is worth to begin the presentation of our approach with some notation. We have two types of works: those that are completed on time ($D = 0$) and the delayed ones ($D = 1$).What is interesting with respect to all types of works is to understand what makes Pr ($D = 1$) as low as possible. Whereas the duration of the works for which $D = 0$ is quite uninteresting, as it does not exceed expectations, we are very interested in the durations of projects for which ($D = 1$).

Let T denote the positive random variable representing time to work completion for a delayed work. The hazard function $h(t) = \lim_{\partial t \to 0} \left(\frac{\Pr(t \leq T < t + \partial t \mid T \geq t)}{\partial t} \right)$ expresses the probability that the completion of a delayed work occurs exactly at time t for works that were not completed earlier and, therefore, are still at risk of completion at the beginning of t. Note that we are not always able to observe the actual execution duration of the delayed works: we know it only if the work is completed before the end of the time period covered by the available data, otherwise all we know is that the execution time exceeds the observation time. In other words, the execution times of delayed works are right-censored, which occurs in 39.5% of cases (Table 2). Under these circumstances, duration models are the appropriate tool to analyse the data (e.g. Box-Steffensmeier and Jones, 2004).

A straightforward way to analyse time to completion is to write a regression model where the hazard of completion of each given work, $h_w(t)$, is a function of a baseline hazard function $h_b(t)$ and the vector of explanatory variables $\boldsymbol{x}_w$. However, as explained above, we know that some works experience a delay, while others do not. Therefore, similarly to what happens with other classes of two-part models (e.g. hurdle models, see Wooldridge, 2010), we can write our model as follows:

$$h_w(t) = \Pr(D_w = 1|\boldsymbol{x}_w) \times h_w^*(t \mid D = 1, \boldsymbol{x}_w^*)$$

where h_w^* is the conditional hazard that can exist only when $D = 1$ or, equivalently, when $T > 0$.The assumption that D and h^* are independent conditional on explanatory variables is required and implies that estimation can be carried out separately for each part (Schmidt and Witte, 1989). Note that the explanatory variables in the two parts do not have to be the same; in case they are the same they can be expected to play – based on theory or simply on common sense – a similar or also a different role in the two parts of the process.

As for the first part, the probability of delay must be estimated by means of a generalised linear model, which requires the specification of a nonlinear function such as a logit: $logit\{\Pr(D_w = 1|\boldsymbol{x}_w) = \beta_0 + \boldsymbol{\beta}\boldsymbol{x}_w\}$. The coefficient vector $\boldsymbol{\beta}$, estimated through the maximum likelihood method, represents the change in the log odds ratio of having a delay for a one unit increase in the related explanatory variable with respect to the situation where all $\boldsymbol{x}_w = 0$ (or equal to a base level if the variable is binary or categorical).[6]

Coefficients can then be applied as follows in order to recover probabilities:

$$\Pr(D_w = 1|\boldsymbol{x}_w) = \frac{\exp(\beta_0 + \boldsymbol{\beta}\boldsymbol{x}_w)}{1 + \exp(\beta_0 + \boldsymbol{\beta}\boldsymbol{x}_w)} .$$

As for the second part, we need a duration model where the hazard of completion of each given delayed work $h_w^*(t)$ is a function of the baseline hazard function $h_b^*(t)$ and the vector of explanatory variables $\boldsymbol{x}_w^*$. Before proceeding with further details, however, one important issue needs to be pointed out. We know that works can be characterised by different degrees of complexity that result, for example, into different expected durations (Chong et al., 2014). Suppose

[6] As will be illustrated in Section 5, the baseline work is a road maintenance awarded through negotiation by a very small, inexperienced municipality. The work value equals the mean of all works.

there are two groups of works: in the first group, work execution is expected to last, say, one month, while in the second group it is expected to last one year. If these works are delayed, 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. In order to address the latter issue, we choose to carry on our analysis using 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:

$$h^*_w(t) = h^*_{b,g}(t)\exp(\boldsymbol{\beta}^* \boldsymbol{x}^*_w) .$$

We define the strata of expected durations after a careful inspection of the hazard functions that are obtained under different grouping scenarios. In particular, we follow a bottom-up approach as follows: first, we split our sample of delayed works into a wide number of groups based on different moments (percentiles) of the distribution of expected durations; then, we compare the hazard functions of these groups and merge those groups whose hazard functions have similar shapes. This process leads to identify four final strata: i) delayed works whose execution was expected to last up to 3 months; ii) between 3 and 4 months iii) between 4 and 7 months; iv) longer than 7 months. For each one of these strata, the baseline hazard function $h^*_{b,g}(t)$ describes the risk for works with $\boldsymbol{x}^*_w = 0$. Baseline hazard functions related to the four strata above are illustrated in Figure 1(A).

The coefficients $\boldsymbol{\beta}^*$, estimated through the partial likelihood method, suggest us what happens to the risk of completion of delayed works in response to a one-unit change in each variable, all the rest being equal. By exponentiating these coefficients, we obtain hazard ratios:

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

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

A final remark regards how the standard errors related to the coefficients of the models above are estimated. In fact, each work *w* belongs to a municipality, our data have a grouped structure that make it quite plausible that two or more works that fall under the same municipality are correlated. The use of a cluster-robust (at the municipality level) estimator of the standard error is recommended in order to tackle this issue (Cameron and Miller, 2015).

5 Model specification

This Section is devoted to illustrate which explanatory variables are comprised in the vector $\boldsymbol{x}_w$ and how they are inserted in the model. Based on the dataset presented in Section 3, we know about expected (contractual) and actual durations and about a number of other work characteristics. Since we can trace each work back to a municipality, we also consider some variables defined at the municipality level. Finally, one variable, namely experience, is defined at the work level but as a function of the municipality's procurement history. Descriptive statistics on these variables are reported in Table 2. Before proceeding with the description of the variables, an important thing to note is that 65.3% of works incur delays, which justifies the approach presented in Section 4, and that these delays have a non-negligible average duration.

A first important variable is the work value. The use of this variable is standard in empirical analyses on public procurement, where it is regarded, similarly to expected duration, as a proxy of work complexity (Chong et al., 2014).

The variable related to the auction process expresses the degree of potential competition characterising the tendering procedure. Here, we follow the classification put forward in Decarolis et al. (2010). Auctions are classified depending on whether they award the contract to the lowest-

priced bid (first-price auction), to the lowest-priced bid after the exclusion of abnormal tenders (average bid auction) or to the bid that, after screening, is judged as the most economically advantageous one (scoring rule). Negotiations are split into two groups: standard negotiations and piecework contracts for minor works.
A couple of other interesting variables related to works, often found in previous empirical literature, describe the public work's sector and type. As to the former, local administrations operate in a wide range of sectors, such as building, road or other transport infrastructure, environmental protection, cultural goods, etc. We describe works using a categorical variable for the main sectors observed in the data. The type of work, instead, is described by a binary variable taking the value of one if the work consists of the creation of a new infrastructure, and the value of zero if it is rather aimed at its maintenance or restoration.
Let us now focus on the variables that are more interesting relative to our goals and/or original with respect to previous literature.
Motivated by the recent contribution by Guccio et al. (2014a), who find that peripheral buyers - especially very small municipalities - are associated with longer delays than the central government, we split the 196 municipalities into classes based on resident population, in order to verify to which extent execution times depend on the municipality size.
As recalled in Section 2, a relevant phenomenon is that of municipalities reacting to fiscal constraints by postponing payments for public works contracts, which results in increasing arrears (Checherita-Westphal et al., 2015). This issue is clearly shown in Chiades et al. (2015) and in Corte dei Conti (2015) with respect to Italy. If so, a municipality that expands its arrears over time is likely to slow down the timing of public works being executed.

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
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
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
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

In order to construct our variable, we thus calculate each municipality's average yearly percent variation of capital expenditure arrears (over the observation period 2012-2015); creating a dummy variable that assumes value one in case of a positive variation.

During its execution stage, each work is potentially affected also by other characteristics of the municipality, especially by its capacities in managing and monitoring the implementation of the contract. As an example, depending on the level and the quality of the experience of the municipality one could expect it to face more or less difficulties in the management and the monitoring of executions, which might influence execution speeds. Accordingly, by looking at the amount and at the sectors of public works procured during the time period 2009-2011[7], we classify works into three classes: works falling under municipalities with no experience at all (inexperienced)[8]; 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).

We finally describe how the explanatory variables are inserted in the two models presented in Section 4. The work value, which is the only continuous variable, is centred on its mean value, so as to make its baseline (zero) value realistic. Discrete variables are inserted as in Table 2. All the variables enter the models in an additive fashion. We also assess interactions between these variables but, in practice, only the interaction between the work value and the variable related to late payments proves to be statistically significant. Therefore this interaction is the only one that is inserted in the final model specification.

6 Results

The presentation and discussion of the results proceed as follows. First, we briefly comment on the estimated coefficients for each of the two parts of the model illustrated in Section 4 (Table 3, columns 1 and 2). For the sake of completeness, we also report the coefficient of a stratified Cox model for the total duration of works, irrespective of whether they incur a delay or not. Second, we fix some illustrative work profiles and, focussing on the explanatory variables that are of major interest here: i) we predict the changes in the probability of delay in response to changes in these variables; ii) we calculate the hazard ratios associated with any combination of these variables.

Figure 1 depicts the baseline hazard functions for each of the expected work duration strata introduced in Section 4. Note that baseline hazard functions sub (A) enter the second part of the model, illustrated in the previous section, for the delay duration of delayed works only, whereas baseline hazard functions sub (B) enter the model for the total duration of works introduced above.

Accordingly, the Cox regressions coefficients in Table 3, columns 2 and 3, can be applied to reconstruct the shifts of baseline functions reported in the subfigures A and B, respectively.

It can be now useful to mention what the baseline type of work consists of. It is a road maintenance awarded through negotiation, whose value equals the mean of all works (280,261 Euros).This baseline work falls under a very small municipality that does not postpone payments and is inexperienced in following public works of any kind.

Now, by looking at the figures in Table 3, we learn that works with higher expected duration are more likely to incur delays than supposedly shorter works. We also learn that infrastructure construction is associated with higher probability of delay and, ultimately, with longer overall duration than infrastructure maintenance but, once the work is delayed, constructions and maintenances are not necessarily associated with different delay durations. Similarly, works in the

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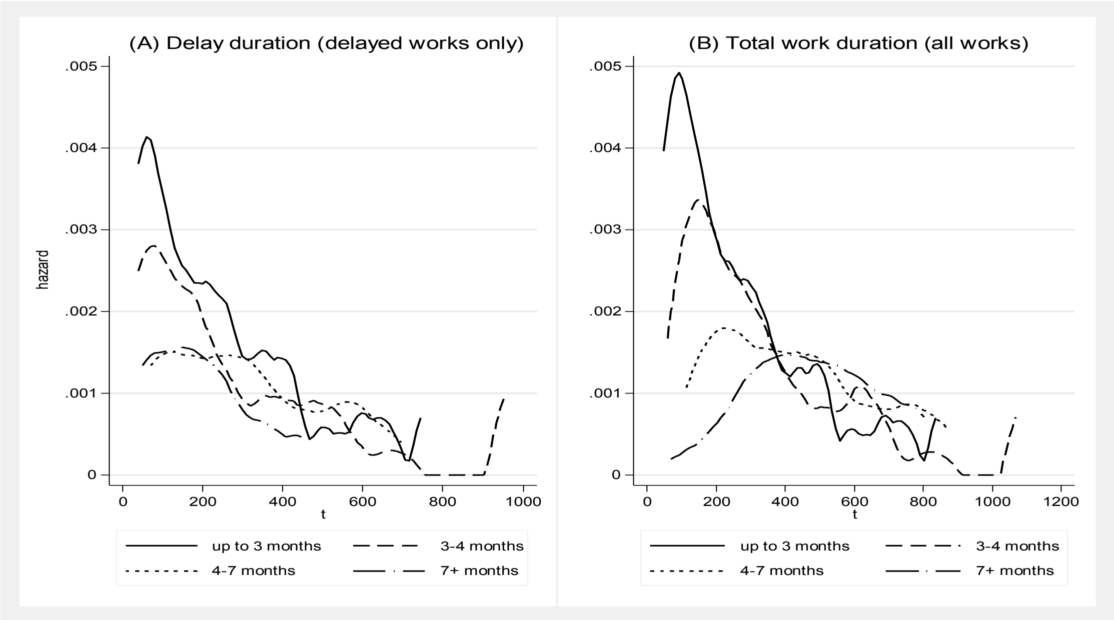
[7]Although micro-data on works prior to 2012 were not provided by the Authority, the latter accepted to provide us with the count of completed works for each municipality, by sector, from 2008 to 2011.

[8] It might be that this class also comprises municipalities whose last procurement experience dates back to 2008 or earlier, which cannot be verified through the available information. If so, the municipality could hardly be regarded as an experienced procurer.

building, environmental and cultural[9] sectors are associated with longer overall durations than roads. This is a consequence of their higher probability of incurring delays, rather than of a higher tendency to get stuck once the delay has occurred.

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



As for the variable related to the awarding process, we find that, although non-competitive procedures turn out to be worse, in our sample, than auctions based on the average-bid or on the scoring criteria, the related coefficients lack of statistical significance, which makes it impossible to conclude with sufficient certainty that competitive procedures really make the difference with respect to delay occurrence, delay duration and the overall duration of works. This result is possibly due to the fact that we are dealing here with relatively small works carried out at the municipality level, for which alternative awarding procedures could bring to barely differentiated results.

Let us now focus on the coefficients related to municipalities. A first point that has to be made, which apparently contradicts previous findings (Guccio et al., 2014a), is that very small municipalities experience neither higher probability of delay, nor longer delay or overall work duration. The most reasonable explanation for this result is that the poorer efficiency of small procuring authorities is not due to the municipality size per se, but is ascribable to factors that are more likely to appear in small authorities. For instance, as shown in Table 4, the works falling under smaller municipalities are less likely to benefit of the experience of a specialised procurer.

Now, the coefficients on this variable reported in Table 3 exactly support this idea. If works are procured by a municipality that has no previous experience their overall duration tends to be longer, due to both higher probability of delay and longer delay duration. Similar results are found if the municipality reacts to budget constraints by postponing payments. Note that, here, the larger the work value, the higher the probability of delay in the presence of late payments.

[9] According to Baldi et al. (2014), restoration works in the cultural sector and maintenance works in the environmental sector are characterised by a higher level of technological complexity than other maintenance/restoration works.

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.
Contractual 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^{**}	0.0056 1
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: $^{*}p< 0.10$, $^{**}p< 0.05$, $^{***}p< 0.01$

Table 4. Proportion, by municipality size, of works relying on different levels of municipality experience

Population:	*Experience*		
	Inexperienced	Unspecialised	Specialised
< 2,000	0.198	0.309	0.494
2,000-5,000	0.081	0.349	0.570
5,000-15,000	0.041	0.241	0.718
15,000-50,000	0.016	0.147	0.837
>50,000	0.000	0.020	0.980
Observations		1,310	

Rather than continue to comment on coefficients, it is convenient to refocus the attention on the more clearly understandable probability shifts and hazard ratios that these coefficients enable us to recover. 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. We can consider a work whatever its type or also look at some of the most typical works in our dataset, such as road maintenances, road constructions or restorations of cultural heritage. With respect to municipality experience levels and to its payment behaviour, we are interested in knowing: (a) the differential probability of delay and (b) the hazard ratio between pairs of experience levels and between the late and the on-time payment situation. These results are presented in Table 5.[10]

Table 5. Differential probability of delay and hazard ratios between pairs of experience levels and between alternative payment behaviours by a very small municipality contracting out by negotiation a work of average value and contractual duration exceeding 7 months

	Experience			*Postpones payments*
	Specialised vs Inexperienced	*Unpecialised vs Inexperienced*	*Specialised vs Unspecialised*	*vs Does not postpone payments*
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 computed by Delta method based on a covariance matrix that is cluster-robust at the level of municipality.
Statistical significance: *p< 0.10, **p< 0.05, ***p< 0.01

As to the procurer's experience, look, for instance, at a work of whatever sector or type: if it is procured by a municipality which does not postpone payments and has previously managed works in the same sector (specialised), this work enjoys i) a 13.3% lower probability of incurring delays, ii) in case it incurs delay, a 99.4% (i.e. 1.994 - 1) higher hazard of conclusion and iii) a 95.2% higher hazard of conclusion throughout, than in the situation where it is managed by an inexperienced municipality. In words, the specialised experience of the municipality not only makes it more likely that the work is completed on time, but also, in case it is not, it halves the duration of its delay. To sum up, it makes the work proceed, approximately, at double speed. Although less pronounced and surrounded by a slightly higher uncertainty, similar benefits are also associated with unspecialised experience: here, our work has a 10.2% lower probability of incurring delays and, if delayed, a 72% higher hazard of conclusion than in the situation where it is managed by an inexperienced municipality. Similar results apply when considering road maintenance, road construction and heritage restoration works. Although the direct comparison between sector-specific experience and generic experience (third column in Table 5) does not allow us to conclude that the former experience level surely outperforms the latter, it seems to us that the evidence reported so far clearly points out that the lack of procurement experience is a serious issue that calls for appropriate remedies.

[10] In the case of the generic type of work, Table 5 reports the difference between average adjusted predictions, which can be interpreted as the shift in the probability of delay that occurs on average as a consequence of a one-unit shift in a given explanatory variable, all the other explanatory variables related to the type of work left at the level that is actually observed in the data. These latter explanatory variables are then fixed at specific values in order to obtain predictions that are specific to each work profile (Williams, 2012).

Finally, let us focus on late payments. We consider, again, a work of whatever sector or type and suppose that these payments are postponed by a municipality that can rely on previous sector-specific procurement experience. Postponing payments entails a 13% higher probability of delay (as for specific work profiles, this probability shift ranges from 11% to 17%), a 44% lower hazard of conclusion for delayed works and a 40% lower hazard of conclusion throughout. To sum up, late payments not only make it more likely that the work is delayed, but also they almost double the duration of delays.

7 Conclusions

This article has studied the timing of execution of public works procured by municipalities, aimed at the creation and maintenance of local infrastructures. This kind of public works, despite being relatively small in size, are not exempt from undesirable delays. A relevant issue in procurement policy and design refers to if and how procurement performances of municipalities can be improved. 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.

Our article provides a proper statistical analysis of the role of municipalities' procurement experience in explaining the duration of public works. In so doing, it adds to the previous empirical studies on procurement that have mostly focussed on the investigation of contract awarding procedures or have approached the issues regarding municipality-level procurement in a less explicit fashion. Another element of novelty characterising this work, which should attract the attention of scholars, lies in the use of survival analysis techniques to investigate work durations.

Using administrative data on the works recently procured by the municipalities of a large Italian region, Tuscany, we find that insufficient procurement experience is associated with a higher probability of incurring delays and with substantially longer delay durations. Our findings also show that municipalities that postpone payments in response to budget constraints are more likely to face delays and longer work durations. All this suggests that some form competence upgrade should be pursued with relatively inexperienced municipalities in order to oppose time escalations in public works. This upgrade could be even more desirable in a season of budget austerity. For this purpose, our opinion is that resource and competence pooling could be a first, feasible step in the right direction that should be encouraged by legislators. This pooling could occur, for example, by favouring the exchange of experiences, by the identification and mainstreaming of best practices, or through the creation, by the municipalities themselves, of joint service centres at the level of intercommunalities.

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