Subcontracting in Public Procurement: an Empirical Investigation*

Luigi Moretti
University of Padova

Paola Valbonesi
University of Padova

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Abstract

We assemble a new dataset and empirically investigate the effects of subcontracting on the bidding price in auctions for awarding public contracts in Italy. We look at the Italian system for the preliminary qualification of firms bidding for public contracts to shed light on different subcontracting formats. Under the provisions of this system, bidding firms can be classified as either partially or fully qualified to complete a tendered project. The former are obliged to allocate certain tasks involved in the contract to other qualified firms, giving rise to a mandatory vertical subcontracting. The latter are free to choose whether or not to subcontract some tasks to similarly qualified firms, adopting a horizontal subcontracting format. We find that firms in a position to subcontract horizontally generally offer higher rebates (i.e. lower prices) than firms having to subcontract vertically. This result, which holds true after controlling for auction characteristics, firms' fixed effects, and characteristics of the subcontract, indicates that firms apply different price reductions to different subcontracting strategies in the public procurement supply chain.

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Keywords: regulations for subcontracting in procurement, firm's production strategy, horizontal subcontract, vertical subcontract, public procurement.

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1 Introduction

Subcontracting usually involves "a reallocation of production requirements among firms" (Kamien and Li, 1990, p.1354), a process which is part of the firm's strategic production planning decision. In specific markets, regulation may transform these production requirements into constraints under which the firm needs to maximize its objective function, and could consequently lead to distortions in the firm's efficient choice. In this study we focus on regulation in the public procurement market affecting firms' subcontracting, aiming to empirically capture effects on the production chain efficiency.

Subcontracting in public procurement is amply regulated in terms of both quantitative and qualitative requirements, for two main reasons: because the public resources conveyed through these contracts are often specifically intended for affirmative actions (i.e. programs indirectly encouraging the participation of disadvantaged businesses by means of subcontracting schemes); and to prevent illicit or undesirable behavior in the awarding of the contract and the completion of the works (i.e. corruption, collusion or competition softening, poor-quality execution).

Concerning the former reason, the picture emerging from empirical evidence of the effects of subcontracting requirements designed to support disadvantaged business enterprises (DBE) programs is rather unclear. Marion (2009) examined one such DBE program implemented by the California Department of Transportation, finding that the average price of items on state-funded contracts fell by 5.6 percent after this affirmative action was abandoned. Conversely, De Silva et al. (2012) looked at a DBE program adopted in Texas and found no differences in bidding and prices between projects with and without such subcontracting goals.[1]

As for the latter reason for regulating subcontracts, to the best of our knowledge no empiri-

[1]Marion (2009) exploited a modification of the law (prompted by California's implementation of Proposition 209 in March 1998), which eliminated the preferential treatment in contracts not using federal funds, to identify the impact of affirmative actions on the winning bids for highway construction contracts. In De Silva et al. (2012), this impact was captured by comparing projects in which prime contractors were obliged to subcontract a portion of highway procurement projects to DBE firms, and projects in which they were not. The different approaches might well contribute in explaining the different results.

cal work has investigated how such regulations affect - through outsourcing - efficiency (i.e. pricing) and/or the performance of contracted works in the public procurement setting.[2] This is surprising, considering that public procurement accounts for about 15 percent of the GDP in developed countries: such a big business deserves a clear understanding of which rules are best to ensure that contractors make efficient subcontracting decisions.

This paper aims to contribute to filling this gap. We assemble an original database of Italian public procurement contracts awarded by means of open tenders and containing information about bidding firms (i.e. potential contractors). As in many other countries, Italian regulations on public procurement require that firms undergo a preliminary qualification process before they enter the public contract market, and that every task in public contracts be completed by such qualified firms (see Section 2 below).[3]

These requirements affect firms' make-or-subcontract decisions in two ways. First, *if a firm is not qualified to complete all the tasks involved in a given contract*, its production planning strategy has to take into account a "mandatory" subcontracting agreement with another firm qualified to do so. Second, *if a firm is fully qualified for all the tasks involved in a given contract*, its production planning strategy may or may not involve subcontracting a part of the work to a similarly qualified firm. In the former case, subcontracting is unavoidable and belongs to a vertical integration of production, i.e. an agreement between firms with complementary capabilities/assets with a view to obtaining a final output (Webster et al., 1997), what we define here as *mandatory vertical subcontracting*. In the latter case, any subcontracting would be part of a horizontal disintegration of production, i.e. an agreement between rival firms "each of which is capable of producing and marketing its product independently" (Spiegel, 1993), that we have termed as *optional horizontal subcontracting* because the firm can choose whether to complete the project alone or to

[2]Converserly, there are numerous theoretical and empirical contributions on which auction design better ensures both the lower awarding price and the better contractual performance (see, among others: McAfee and McMillan (1986), Manelli and Vincent (1995), for the former; and Bajari et al. (2009), Cameron (2000), Decarolis (2012) and Bajari and Lewis (2011)for the latter).

[3]Qualifications are needed to enter the national market for public contracts in many EU countries, the USA and Japan, though the design of these systems and the criteria adopted differ somewhat. For a few examples, see the OECD (2007).

outsource (horizontally subcontract) a part of the work to other firms.[4]

In the public procurement setting investigated here, firms bidding for tendered projects offer reductions on the reserve price set by the contracting authority (CA), i.e. a reverse auction takes place. For each tendered project, firms know their subcontracting position (mandatory vertical or optional horizontal) in advance and bid accordingly. The two subcontracting conditions are likely to differ in terms of the potential cost of fulfilling the contract, with a consequently different fallout on production efficiency. Our aim was precisely to capture any such difference empirically, by investigating firms' behavior in bidding for Italian public procurement tenders. It should be noted that the same bidding firm may be fully qualified for one tendered contract, and only partially qualified for another, depending on its qualifications, so its mandatory vertical or optional horizontal subcontracting behavior is determined contract by contract.

Our datasets contain details of the qualifications needed to bid for each contract (i.e. the categories of work or tasks to be completed) and the qualifications held by each bidding firm. For each contract awarded, we can therefore distinguish between the bids offered by partially-qualified firms (that will have to engage in vertical subcontracting if they win) and fully-qualified firms (that may choose to complete the works alone or to horizontally subcontract a part of them). Adopting a reduced form approach and checking for auction-/project-related characteristics and firms' fixed effects, we found that bidding firms in a position to choose whether or not to horizontally subcontract a part of the work offered larger rebates (i.e. lower prices) than those obliged to vertically subcontract a part of the work. This effect was still significant when we focused on the bids made by the winning firms that actually did engage in subcontracting, i.e. the horizontally subcontracting firms offered a lower price than the vertically subcontracting firms. Given the regulations on subcontracting in the public procurement market, our findings indicate that the production efficiency deriving from subcontracting is higher when it is an option

[4]In settings where a firm's decision whether to make or subcontract is not imposed by any regulations, the literature usually distinguishes between vertical and horizontal subcontracting using the terms "specialization" and "capacity" outsourcing, respectively.

and not an obligation for the firm concerned and when it has a horizontal form.[5] We find the explanation for this result in the interplay of different factors as follows. If a firm can choose to subcontract horizontally, it will do so only if it is profitable. Horizontal subcontracting also implies outsourcing a part of the works to "similar and known" firms and this entails lower search costs as well as a greater information symmetry concerning the execution costs. Finally, the fact that a firm can choose whether or not to outsource some of the works and the greater information symmetry combine to generate a stronger bargaining power in horizontal than in vertical subcontracting transactions.

Our empirical findings confirm Spiegel's theoretical results (1993) that horizontal subcontracting facilitates improvements in a firm's production efficiency (and total welfare). Spiegel's results were obtained, under mild assumptions, in a Cournot setting, where the firm's cost function is strictly convex and subcontracting enables cost cutting by shifting production from firms with high marginal costs to others with lower marginal costs.[6] Our empirical setting reveals that, when firms are not constrained in their subcontracting decisions, horizontal subcontracting can improve their cost-related efficiency more than in firms liable to mandatory vertical subcontracting.

To the best of our knowledge, ours is the first empirical investigation to be conducted on the effects of subcontracting formats, determined by regulations in the public procurement market, where the production efficiency achievable by the contractor by subcontracting a part of the work has a direct influence on social welfare. The rebate offered by the bidder correlates with the contractor's expected costs to complete the contracted works, and the higher the winning bidder's discount, the lower the price the CA will have to pay for the works, and the greater the gain for the welfare of the community.

The remainder of this paper is organized as follows. Section 2 describes how public pro-

[5] In a competitive stochastic investment game, Van Mieghem (1999) investigated the firm's choice of subcontracting as an option value, finding that it improves its financial performance and coordination on investment.

[6] A further theoretical finding relating to horizontal subcontracting was obtained by Kamien et al. (1989) in a Bertrand setting, where firms first compete to win a contract, then have the chance to use subcontractors. This study showed that firms bid less aggressively when the subcontracting terms are set at the bidding stage by the loser than when they are set by the winner.

curement auctions and subcontracting work in Italy, giving more detailed information on the datasets on which we based our investigations. Section 3 presents the econometric model, the empirical results and the tests performed on their robustness, considering all the firms' bidding price reductions. Section 4 illustrates the results of our estimations, focusing on the reductions offered by the winning bidders, i.e. the firms that won and fulfilled the contract. Conclusive comments are given in Section 5.

2 Procurement auctions and subcontracting in Italy

For an empirical investigation into how procurement regulations affect a firm's production strategy when it comes to subcontracting, we considered the bidding details concerning Italian auctions held to award public contracts. Auctions are generally a good way to reveal agents' value in a competitive setting and, in the specific reverse auction procurement setting considered here, analyzing the bids is a good way to infer the costs incurred by firms in fulfilling contracts they win.

According to Italian law on public procurement, a firm must be qualified to bid for contracts for public works worth more than 150,000 Euro.[7] The Italian system for qualifying contractors is operated by private companies (called SOA) accredited and monitored by the AVCP[8] that certify a firm after ascertaining that it meets the established requirements. These requirements are classifiable as general and technical, and they define the supply side of the market for public works. The general requirements concern the firm's financial standing and criminal records and are the same for any firm wishing to take part in public procurement auctions. The technical requirements have to do with the specific technical skills needed for a firm to be able to perform certain works. Depending on their expertise, candidate firms are qualified for one or more of 46 categories of works involved in the public works system. Their qualification for each category remains valid for 5 years

[7] See: Italian Law No. 163/2006.

[8] "Autorita' di Vigilanza sui Contratti Pubblici di Servizi, Lavori e Forniture", i.e. the Italian authority for monitoring and regulating the national market for public works and services.

(after which it is renewable), and it certifies to the size (i.e. the value) of the contracts and the work categories that a firm is allowed to take on.

Turning now to the demand side of this market, contracts are typically awarded by local CAs, which specify the qualification(s) needed for each project being tendered, distinguishing between a *main* work category and *other* categories. For instance, if the construction of a road is put out for tender, the *main* category involved will be OG3, where OG3 refers to the "road building" category. The contract usually also involves *other* (secondary) categories of works forming part of the project (e.g. hydraulic works on the river close by the road). For the *main* work category in the contract, bidding firms must have the required qualifications based on their own resources.[9] Alternatively, firms that lack this qualification can participate as part of temporary consortia (called "Associazioni Temporanee d'Impresa", ATI, which are associations of firms - consortia - created *ad hoc* to bid for a given contract, for which at least one of the associated firms is qualified).[10]

For the *other* categories of works involved in a public contract up for auction, the bidding firm may be either fully or partially qualified. In the former case, the firm winning the contract can choose either to complete all the works on its own or to subcontract parts of the works to other similarly qualified firms (i.e. rival firms with much the same qualifications, so we call this optional horizontal subcontracting). If a firm is partially qualified, on the other hand, it can still bid for the contract, but if it wins it is obliged by law to subcontract the works for which it has not been qualified to other firms that have the necessary qualifications (we call this mandatory vertical subcontracting).[11]

On the whole, the aim of this system is to accept bids only from firms that are capable

[9] In the *main* work category, bidding firms may not subcontract more than 30% of the value of the works. If firms use subcontractors for this main category of works, this is a case of optional horizontal subcontracting according to our definition.

[10] We can reasonably assume that consortia bidding for tendered contracts are qualified for all the categories of work involved in the project, since each consortium is established *ad hoc* for a particular project.

[11] As a remote alternative, the firm can lease the qualification it lacks from a qualified firm that is not bidding for the contract. It is not possible from our data to distinguish between vertical subcontracting and such qualification leasing (called "avvalimento"), but the latter is rarely used because it entails a very expensive agreement; it can also be considered as a form of vertical subcontracting since the firm is not qualified to do the work on its own.

of completing the contracted works efficiently (and officially qualified to this effect); if they are not, they are obliged to subcontract the works for which they are not qualified to other qualified firms, since all aspects of the project involved must be handled by firms qualified to do so. A noteworthy effect of this regulation of the public procurement market is that, when a contract is tendered, it specifies the potential position of firms concerning any subcontracting: each tender defines the categories for which bidding firms should be qualified. This means that each firm bidding for the public contract is aware that, if it wins, it may, outsource some of the tasks for which it is fully qualified if it wishes, or it will be obliged to subcontract certain works for which it is not qualified.

Since each bidding firm includes an assessment of its production strategy in its bid for a contract, our dataset enables us to make a distinction between the two subcontracting formats in terms of the bidding firms' expected costs. For the sake of our analysis, it is important to bear in mind that, within the framework that we investigated, the same bidder may be in a position to consider optional horizontal subcontracting for some contracts, while being obliged to resort to mandatory vertical subcontracting in others.

2.1 Data

Different sources of data were used to assemble our original dataset for the purposes of the present analysis. To obtain information on each public contract tendered, we referred to a hitherto unexploited dataset, collecting transcripts of competitive auctions conducted from 2000 to 2009 by the Regional Government of Valle d'Aosta.[12] Each transcript contains details of the auction ID, the number of bidders, the bidders' names, and the rebates they offered. The auction ID enabled us to access other details from a national dataset managed by the AVCP on each contract tendered having a reserve price higher than 150,000 euro: this dataset includes information on the contract allocation procedure, the bidding rules adopted, the value of the contract, and the work categories involved.

[12]Valle d'Aosta is a small, mountainous Italian region with a population of 128 thousand on Italy's north-western borders with France and Switzerland.

Information was also extracted from another national AVCP dataset known as the "Casellario SOA", a sort of register collecting the qualifications of each bidder for each work category involved in the contract up for auction.

Summing up, for each contract tendered, we have information on all the qualifications required (by the CA) for completion of the tasks involved in the project and all the actual qualifications boasted by each bidding firm. Matching these data enabled us to identify the bidding firms that would be obliged to vertically subcontract a part of the works because they were not fully qualified to complete them.

Our dataset consists of public contracts awarded by CA by means of open tenders, where firms participate by offering a percentage reduction on the reserve price set by the CA.[13] Once the CA has identified the bidders that meet the legal, fiscal, economic, financial and technical requirements, the contract is awarded according to the rules governing the auction. We have the details for all the public contracts awarded from 2000 to 2009 by the Valle d'Aosta Regional Government by means of open tenders and average-price auctions.[14]

Our dataset covered 269 auctions for public contracts, for which a total of 13,317 price reductions were offered by bidders consisting of 891 firms and 1,777 temporary consortia. The average reserve price of the contracts awarded was approximately 1.1 million Euro (ranging from a 155 thousand to 5.2 million Euro). As shown in Table 1, which includes further summary statistics, these contracts refer mainly to road works (37.2%), river and

[13] According to EU directives, in Italy public procurement can be released through four types of awarding procedures: open, restricted, and negotiated procedures, and competitive dialogue. In our study, we consider only cases involving open tenders ("pubblico incanto"). Participants in restricted and negotiated tenders are invited by the CA, and including such cases in our analysis might bias our results because the CA could invite firms with particular features and qualifications. We have no data concerning contracts awarded using competitive dialogue procedures.

[14] The average price mechanism can be briefly described as follows: given the distribution of all bids received for an auction, the bids located in the first and last deciles are excluded and the winning bid is the one immediately below an anomaly threshold resulting from the sum of the average bid (the simple average of all not-excluded bids) and the mean deviation of the bids above said average bid. See Figure 1 in Appendix B for an illustration of the mechanism. This auction mechanism was applied to 89.2% of our sample. For the other 10.8% of the sample, a similar average price mechanism was combined with a sort of lottery; see Appendix A for a description of the variables); see Decarolis (2009) and Albano et al. (2006) for a discussion of the average price mechanism.

hydraulic works (29.7%), and special structural works (7.8%).

Table 1: Descriptive statistics: characteristics of auctions/projects

Bid-level data					
Variable	Obs.	Mean	St.Dev.	Min	Max
Rebate (%)	13317	17.215	4.829	0.001	43
Reserve price (Euros)	269	1103786	865298.5	155526.3	5267860
No. of participants	269	55.450	31.845	3	155
Expected duration (days)	269	328.640	172.645	79	1440
Average price	269	0.892	0.311	0	1
Average price + lottery	269	0.108	0.311	0	1
Road works	269	0.372	0.484	0	1
River and hydraulic works	269	0.297	0.458	0	1
Buildings	269	0.078	0.269	0	1

See Appendix A for the definition of variables.

As shown in Table 2, 73.8% of the bidders participating in the auctions in our sample had all the qualifications required (so they could opt to horizontally subcontract a part of the works if they wished), while 12.8% participated although they were not qualified for some of the secondary categories of works (and they would consequently be obliged to subcontract them vertically to other firms). The other 13.3% of the firms belonged to consortia. The firms' subcontracting status often varied, depending on the tasks involved in a given contract: this was the case of 75% of the bidding firms, which took part in auctions sometimes with one potential subcontracting status, sometimes with the other. About 23.6% of the bidding firms (including consortia) were always in a position to choose the horizontal subcontracting status and about 1.4% would always have been committed to adopting the mandatory vertical subcontracting status.

Descriptive statistics for our sample give us a clear idea of the local dimensions of the market for public procurement works in the Valle d'Aosta. Approximately 35.9% of the participants in the auctions (corresponding to 32.9% of the bids) were firms located in the region, 26.6% (21.5% of the bids) came from the larger neighboring Piedmont region, and

approximately 20.3% of the participants (23.6% of the bids) from other parts of northern Italy; the remaining 17.2% (22% of the bids) came from central or southern regions of Italy. In terms of the price reductions offered by bidders, local firms (those from Valle d'Aosta) slightly differ significantly from outsiders: the former offered an average discount of 16.98%, which is slightly lower than the mean 17.32% of the bids made by the latter.

Table 2: Descriptive statistics: bidders' characteristics

	% of the sample
Local bidders	32.90
Bidders' size:	
small	11.69
medium	53.08
large and co-operatives	21.90
Consortia	13.33
Subcontracting status (% of sample):	
Mandatory vertical	12.83
Optional_Horizontal (excluding consortia)	73.84
Subcontracting status (% of bidders):	
Mandatory_Vertical	1.39
Optional_Horizontal and Mandatory_Vertical	75.00
Optional_Horizontal (excluding consortia)	10.28

See Appendix A for definition of variables.

3 Analysis of the bidding rebates

3.1 Testable hypothesis and model specification

In this Section, we consider the discounts offered by all bidders at auctions for public procurement contracts. As in many other contributions to the literature on public procurement in which contracts were awarded by means of reverse auctions, the bids were investigated because they represent the value attributed by the firm to the project, i.e. what the firm expects it to cost to complete the works plus a mark-up. The average bid

auction mechanism adopted in the tenders for public contracts investigated here is known to produce multiple equilibria (Decarolis, 2009). We simply assumed, therefore, that the firms' estimate of the costs of completing a given project provided the grounds on which they based their bidding behavior.

As discussed earlier, subcontracting in this procurement setting may be seen as a planning tool or as a planning constraint in the firms' production strategy, with consequently different effects on their expected costs, and therefore on their bids. Our testable hypothesis is that there might be a significant difference in the amount of discount offered between firms obliged to subcontract vertically and those in a position to decide whether to complete the contracted works alone or with the aid of horizontal subcontractors.

A simple two-group mean-comparison test (Table 3) showed that the average rebates offered by firms obliged to subcontract vertically were significantly lower (i.e. their prices were higher) than those offered by firms that could subcontract horizontally; the situation remained the same after excluding the consortia from the sample.

Table 3: Correlation: Subcontracting format and bidding rebates

	Average rebate	Average rebate (excluding consortia)
Optional_Horizontal	17.35	17.34
Mandatory_Vertical	16.27	16.27
Difference	1.08***	1.07***

See Appendix A for definition of variables.

This descriptive evidence might be due to various factors associated with the characteristics of the firms concerned, e.g. their production capability, financial position, productivity, location and associated logistic costs/problems, but also with the type of auction, the dimensions of the project, and the categories of works involved. For instance, firms qualified for more categories of works might be more likely to be fully qualified because they are larger and/or more efficient. To check for all such factors and grasp the differences in

the price reductions offered by bidders in different subcontracting roles, we estimated the following model specification for bidding rebates:

$$Rebate_{ij} = \alpha + \beta_1 Optional\_Horizontal_{ij} + \beta_2 Q_j + \beta_3 X_i + \epsilon_{ij}. \quad (1)$$

where $Optional\_Horizontal$ is a dummy variable with a value of 1 when the firm i is in a position to complete the works alone or subcontract a part of them horizontally (it is fully qualified to handle the project j) and a value of 0 otherwise (i.e. in the position of mandatory vertical subcontracting). Q_j is a set of variables to adjust for the nature of the project and auction (i.e. proxies for characteristics of the project such as its dimension or complexity and the type of work involved, and proxies for the auction's characteristics, such as the type of auction and the level of competitive pressure, and year dummy variables to adjust for temporal shocks that might have affected both the time-related trends of the firm bidding behavior and the contracts chosen by the CA). X_i represents a set of features of the firms (such as a proxy for the firm's size),[15] and ϵ_{ij} is the error component. To contain the omitted variable problems, in some specifications, we also included firms' fixed effects to adjust for firm-specific characteristics (e.g. size, productivity, financial position, location): this enabled us to focus on the within-firm variation in horizontal or vertical subcontracting status, and to better capture the effect of changes therein. These firm-specific characteristics could also vary over time, so in different specifications of the model we also adjusted for firm-year fixed effects.

3.2 Estimation results

Our primary coefficient of interest is β_1, which indicates whether a firm's subcontracting status influences its bidding discount. This coefficient reflects the difference between the price reductions offered by firms that can choose to subcontract horizontally vis-a-vis those obliged to subcontract vertically. To deal with the potential heteroschedasticity issues, we

[15] As we do not have data on the size of the firms, we use the types of business entity as a proxy. See Appendix A for more details on the definitions of the variables.

use ordinary least squares (OLS) estimates with robust standard errors, clustered at firm level (to enable within-firm observations to be correlated).

Table 4: Estimation results: bidding rebates

Dependent variable:	Bidding Rebate		
Mean outcome:	17.21	17.15	17.23
	OLS	OLS	OLS
	1	2	3
Optional_Horizontal	0.212**	0.323***	0.363***
	(0.097)	(0.100)	(0.110)
(log of) Reserve price	0.154**	0.205***	0.220***
	(0.069)	(0.078)	(0.079)
(log of) Expected duration	-0.294***	-0.294***	-0.375***
	(0.095)	(0.110)	(0.116)
(log of) No. of participants	1.206***	1.298***	1.261***
	(0.142)	(0.153)	(0.164)
Category of work dummy	YES	YES	YES
Type of auction dummy	YES	YES	YES
Firm size dummy/Cons.	YES	NO	NO
Firm fixed-effects	NO	YES	NO
Firm-year fixed-effects	NO	NO	YES
Year dummy	YES	YES	YES
Observations	13,317	9,988	9,600
Adj. R-squared	0.519	0.543	0.575

Note: See Appendix A for definition of variables.
Robust standard errors clustering at firm level in parentheses.
*** p<0.01, ** p<0.05, * p<0.1.

Our results are given in Table 4, columns 1-3: they show that the coefficients for the *Optional_Horizontal* variable always have a positive sign and are statistically significant. This means that, all else remaining equal, firms fully qualified to complete a project (that may or may not subcontract part of the work horizontally as they wish) offer significantly greater rebates than firms that would be obliged to vertically subcontract out a part of the works. In particular, the former offer approximately 0.2-0.3% larger discounts than the latter.

These findings go to show that a bidding firm's production efficiency benefits (i.e. its production costs are lower) when its subcontracting position is flexible and would entail contracting out a part of the project to similar firms; this is not the case, however, when subcontracting a part of the works to a complementary firm is a binding requirement.

The influence seen on the bids of the two subcontracting formats follows from the interplay of two different combinations, i.e. the optional *vs* mandatory effect, and the horizontal *vs* vertical effect. Unfortunately, from our bidding data for the public procurement setting in Italy it is not possible to separate the two, so we interpret our findings as relating to the following considerations. If a firm can choose to subcontract horizontally, it will do so only if it is profitable.[16] Horizontal subcontracting implies outsourcing a part of the works to "similar and known" firms and this entails lower search costs as well as a greater information symmetry concerning the execution costs. Finally, being able to choose whether or not to subcontract a part of the work and having a greater information symmetry combine to give a firm a stronger bargaining power in horizontal than in vertical subcontracting.[17]

The results of our estimates of the other variables included in the model specifications are consistent with the results obtained in previous empirical studies on the awarding of public procurement contracts. In particular, the coefficients estimated for the reserve price in auctions and for the number of participants are positive and significantly associated with the rebates offered by bidders. It is hardly surprising that the discounts are positively influenced by the size of a project and the number of participants and negatively by the expected duration of the works (both size and duration measures are calculated by the CA's engineers and are known to firms before they place their bid).[18]

[16] Quinn and Hilmer (1994) provided an extended discussion about the firm's relative risks and costs in outsourcing.

[17] In a standard procurement model, where information asymmetry affects the way in which contractors monitor their subcontractors' activities and there are differences in their production costs, Lewis and Sappington (1991) studied the incentive for outsourcing: they found that a contractor opts to use subcontractors when the latter's efficiency is greater than the former's loss of control associated with outsourcing.

[18] In the US, Bajari et al. (2009) showed that having more firms competing in an auction reduces the bidding price. Similarly, in a sample of Italian public procurement auctions, Decarolis (2009), and Bucciol et al. (2011) found that a larger number of bidders increased the amount of the winning bidder's price reduction. Concerning the effect of the reserve price, our results confirm its positive effect on the price

As for the other characteristics of the firms, the model specifications in column 1 of Table 4 include dummy variables for the firms' size. The model in column 2 includes dummy variables for firm-related fixed effects that enabled us to adjust for those features of a firm that do not vary over time (e.g. its location). Finally, the model in column 3 includes dummy variables for firm-year fixed effects that are meant to capture a firm's characteristics (e.g. its size, financial position and productivity) in any given year. Using these dummy variables for a firm's fixed effects in the model also meant that we were able to exclude consortia and firms that -always or never- had all the necessary qualifications from our sample, concentrating only on the bidding firms that were fully qualified for some auctions and partially qualified for others. This was important to avoid any biases in our estimates that might have stemmed from including consortia in our sample (with the corresponding assumptions on whether or not these consortia had all the qualifications); more importantly, it also supports our inference that the overall results were uninfluenced by those firms that always or never had all the required qualifications and allows us to capture the with-in firm variation in subcontracting status.

3.3 Robustness checks

A first concern regarding our estimates has to do with the influence of extreme bids. In fact, it may be that outlying rebates drive the estimation of the coefficient of our *Optional_Horizontal* variable of interest. We deal with this concern by using a robust regression approach (IRLS, iteratively reweighted least squares) that iteratively assigns a lower weight to outlying observations. As shown in Table 5, column 1, the estimated coefficient indicates that a firm's optional horizontal subcontracting status is positive and statistically significant, thus confirming the previous estimates.

A further concern relates to the likelihood of the estimated difference in the discounts

reductions offered, as reported by Coviello and Gagliarducci (2010), and Decarolis (2009). Bucciol et al. (2011) also found that works that were expected to take more time are associated with bidders' higher price reductions.

offered by bidders in mandatory vertical and optional horizontal subcontracting positions being driven by very different distributions of the rebates across auctions. In fact, the numbers of participants and their bids vary across auctions resulting in different distribution of the price reductions at each auction. Even if we control for several characteristics of the auction in the model specification, we might not fully capture the different distributions of bids at each auction. Below we describe two robustness tests performed to study firms' subcontracting status and the distribution of their price reductions.

The average price mechanism adopted to award the public procurement contracts investigated here enabled us to identify different areas in the distribution of the bidding firms' price reductions. In particular, we distinguished the area around the winning discount as follows (see Appendix B): the winning discount in each auction was included between the mean discount and the one corresponding to the 90th percentile of the distribution ("area A"). We focused on this area of the auction-specific distribution of the rebates and we checked whether the previously-estimated difference holds, because previous results might presumably be driven by the fact that bidders liable to mandatory vertical subcontracting tend to offer particularly low discounts, i.e. on the left-hand side of the distribution. If so, we expect two situations. First, subcontracting status might not be the only difference between the two types of bidder (firms that might opt for horizontal subcontracting and those obliged to vertically subcontract some of the works), there might be other differences relating to their productivity and technology. Second, firms bidding in a mandatory vertical subcontracting position would not really be competitive enough to win the auction, and they might take part in auctions for collusive purposes, i.e. to favor a given bidder (or group of bidders).[19]

[19]The analysis of bidders' rebates may suffer from problems relating to a selection bias because the different subcontracting formats could also reflect structural and technological differences that influence the firms' decision to participate in an auction. In our sample, potential bidders were all Italian firms qualified to operate in the public works market, but from our data we cannot estimate the probability of firms participating in auctions because we do not have access to the whole Italian database on such firms' qualifications. Having included fixed effects (and thereby excluded firms that always participated with the same subcontracting status) enabled us to focus on firms that appear to bid in either a mandatory vertical or an optional horizontal subcontracting condition and to exploit within firm variation of subcontracting status. In addition, we noted that the bidders' different subcontracting status did not coincide with

Table 5: Robustness checks: bidding rebates

Dependent variable:	Bidding Rebate		Pr.(Bid.Reb.>Winning Reb.)
Mean outcome:	17.21	18.70	0.093
Sample:	All bids	Bids [mean, 90' perc.]	All bids
	IRLS	OLS	Cond.Logit(OddsRatio)
	1	2	3
Optional_Horizontal	0.154***	0.333***	1.471***
	(0.043)	(0.101)	(0.197)
Res.price/Exp.dur./No.part.	YES	YES	YES
Category of work dummy	YES	YES	YES
Type of auction dummy	YES	YES	YES
Firm size dummy/Cons.	YES	NO	NO
Firm fixed effects	NO	YES	YES
Year dummy	YES	YES	YES
Observations	13,317	3,547	9,988
R-squared		0.763	0.215

Note: See Appendix A for definition of variable.
Robust standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1.

Having made sure that the subcontracting format was not a significant determinant of the bidders' likelihood of offering discounts in "area A" of the auction-specific distribution, we nonetheless found that the difference in the rebates offered by the bidding firms in the two different subcontracting conditions persisted and was still statistically significant (Table 5, column 2). Thus, even when we only considered the bidders in a given auction that offered price cuts coming closer to the winning discount ("area A"), the advantageous position of the firms that could opt for horizontal subcontracting seemed to be reflected in their price reductions.

Finally, we performed a test to estimate the probability of very large price reductions being offered for a given auction. In fact, if firms able to subcontract horizontally are in a better position than those obliged to subcontract vertically, then we should see the optionally

a different probability of their participation in auctions of greater or lesser value, i.e. irrespective of subcontracting status, they were equally likely to bid for smaller and larger projects.

horizontal subcontracting bidders offering very large discounts. After appropriately taking firm-specific characteristics into account, and still assuming that bidding firms (i) do not know how the bids are distributed for a given auction and (ii) decide price cuts according to their subcontracting status, in Table 5, column 3, we estimate the probability of discounts beyond the winning rebate (i.e. the one just below the threshold determined by the sum between mean rebate and a mean deviation of the bids above said average rebate) being offered at a given auction. The coefficient for the *Optional_Horizontal* variable is positive and statistically significant using a conditional logit estimation with the firm's fixed-effects.

4 Analysis of the winning rebates

This Section concentrates on establishing whether the more aggressive rebates offered by bidding firms that can choose whether or not to horizontally subcontract some of the works are part of the assumed potential advantage of this subcontracting format, or due to the fact that such firms will not use subcontractors. To ascertain whether recourse to horizontal subcontracts is actually associated with larger discounts, we checked which of the contract-winning firms that could opt for horizontal subcontracting *actually* used subcontractors to complete a part of the project.

We considered two samples: one consisted of 226 winning discounts drawn from the sample of auctions held by the Regional Government of Valle d'Aosta;[20] the other (which served to test the robustness of our estimates) included a larger number of discounts winning 514 auctions held by several CAs in the Valle d'Aosta between 2000 and 2009. For each project, we obtained information from the AVCP dataset on the extent of subcontracting and the number (and ID) of subcontractors used by the winning firm (see the summary statistics in Table 6).

For the larger sample of contracts (514) we only knew the characteristics of the winning

[20]This sample was extracted from the 269 auctions held by the Regional Government of Valle d'Aosta, for 43 of which we did not have full details of the number of subcontractors used and the value of the subcontracted works. See the upper panel in Table 6 for summary statistics on this sample.

firms and their winning discounts, while we had no information on the bids of all participants in the auctions and their characteristics.[21] For the smaller sample of contracts (226 contracts), the greater amount of information also enabled us to account for the possibility of collusive behavior at the auction stage between the successful firm and the subcontractor: in fact, we checked whether the subcontractors also participated as bidders in the same auction. This was necessary because subcontracting could be used as a way of providing compensation for any collusive agreements between the firms.[22]

Descriptive statistics on the sample of rebates that won the Regional Government's contracts support the impression that there is a slight difference between horizontally and vertically subcontracting firms in terms of their recourse to and management of subcontractors. One might argue that the discounted effect of different subcontracting positions on price reductions might be influenced by the firms' different probability of using subcontractors. We found, however, that about 80% of suppliers actually subcontracted at least a part of the work and, given the participation rate, the two types of bidder had much the same chances of winning and, if they won, of using subcontractors.

We also noted that the two types of bidder awarded subcontracts for similar proportions of the projects' value (on average about 284,000 Euro, i.e. about 1/4 of a project of average size) to subcontractors of similar size (40% of the subcontractors were large firms). When contractor firms could opt to subcontract horizontally, they outsourced to a slightly smaller number of subcontractors (1.8) than when they were obliged to subcontract vertically (2.2), or when they belonged to consortia (2.3). As for the bidding firms'

[21] See the lower panel in Table 6 for summary statistics on this sample. These data were obtained from the AVCP, which collects details of auctions and projects for public works issued by several CAs. In this sample, 57% of the projects were for the Regional Government, 34% for municipalities, and the remainder for other local public authorities, e.g. health commissions and territorial associations for mountainous areas. Note that the smaller set of winning discounts for contracts awarded by the Regional Government is a sub-sample of this larger one.

[22] Contractors that employ subcontractors from among the firms bidding in the same auction tend to choose firms that are performing relatively well (i.e. those offering relatively large rebates). In fact, 74% of these bidder-subcontractors had offered better than average discounts, and 54% had offered larger discounts than the winner. Assuming that the bidding discounts actually reflect the firms' production efficiency (and are not the outcome of collusive strategies), this would indicate that when winners choose subcontractors, for whatever reason, they tend to be well informed and to prefer efficient firms.

characteristics, we also distinguished between local and non-local firms, finding that they were equally likely to use subcontractors (87% vs 89%).

Table 6: Descriptive statistics: winning rebates and characteristics of projects

Procurement projects issued by Valle d'Aosta Regional Government					
Variable	Obs.	Mean	St.Dev.	Min	Max
Winning rebate (%)	226	17.258	4.359	3.62	31.99
Sub	226	0.814	0.390	0	1
Optional_Horizontal	226	0.889	0.314	0	1
No. of subcontractors	226	1.527	1.373	0	7
Value of subcontracts (Euros)	282	231891.5	291335.8	0	1800620
Bidder-Subcontractor	226	0.372	0.484	0	1
Reserve price (Euros)	226	1116571	880810.1	155526	5267861
Number of participants	226	64.991	37.061	3	182
Expected duration (days)	226	324.796	159.325	79	899
Anomaly threshold	226	0.876	0.330	0	1
Anomaly threshold + lottery	226	0.124	0.330	0	1
Road works	226	0.354	0.479	0	1
River and hydraulic works	226	0.323	0.469	0	1
Buildings	226	0.142	0.349	0	1
Procurement projects issued within the borders of Valle d'Aosta by several CAs					
Variable	Obs.	Mean	St.Dev.	Min	Max
Winning rebate (%)	514	16.144	4.779	1.9	36.639
Sub	514	0.772	9.420	0	1
Optional_Horizontal	514	0.710	0.454	0	1
No. of subcontractors	514	1.670	1.923	0	17
Value of subcontracts	514	202304.7	312131.8	0	4726000
Reserve price (Euros)	514	950124.7	856298.8	150000	23315951
Number of participants	514	47.632	35.987	5	182
Road works	514	0.352	0.4781	0	1
Buildings	514	0.198	0.399	0	1
River and hydraulic works	514	0.181	0.385	0	1

See Appendix A for definition of variables.

4.1 Estimation results

To study the rebates offered by winning firms actually engaging in mandatory vertical and optional horizontal subcontracting, we excluded the *Optional_Horizontal* variable from our benchmark model specification (equation 1) and included the variable indicating the firm's actual recourse to subcontracting (*Sub*) and its interaction with the firm's subcontracting status (*Sub*Optional_Horizontal*).

The results are given in Table 7 columns 1 and 3, showing that the *Sub*Optional_Horizontal* interaction term is positive and statistically significant, telling us that when firms engage in subcontracting, they offer larger discounts when they choose to do so (horizontally) than when they are obliged to do so (vertically). While the effect of subcontracting per se (*Sub*) is statistically of no influence. The two different effects of optional horizontal versus mandatory vertical subcontracting on the rebates offered by firms may be responsible for the lack of significance of the average effect of subcontracting per se.

These empirical findings recall Spiegel's theoretical results (1993), i.e. horizontal subcontracting allows subcontracting firms to improve their production efficiency and, in our setting, to offer larger price cuts than firms engaging in mandatory vertical subcontracting. Our estimates indicate that firms' decision to subcontract horizontally is a determinant of the benefit they gain from subcontracting. Indeed, being given the option induces contractors to outsource only when it is profitable, as well as putting them in a stronger bargaining position in negotiations to contract out a part of the works. The same cannot be said of firms obliged to engage in vertical subcontracting. This is confirmed by the results in columns 2 and 4 of Table 7, where the two samples of auctions are restricted to projects where at least some of the work was handled by subcontractors (i.e. the focus in these columns is limited to projects that involved subcontracting). The coefficient estimated for the *Optional_Horizontal* variable is again positive and statistically significant.[23]

[23]To deal with any outliers, we used robust regressions (IRLS, iteratively reweighted least squares), which iteratively assign a lower weight to deviant observations. The average winning discounts were basically distributed in the same way in the two samples, but when the distribution of the winning price reductions was compared with the distribution of all the discounts offered for contracts with the Regional Government of Valle d'Aosta (as discussed in Section 4.1), the presence of outlying observations seemed

Table 7: Estimation results: winning rebates

Dependent variable:	Winning rebate			
Mean outcome:	17.26	17.19	16.14	16.07
CA:	Regional Government		Other Public Admin.	
Sample:	Full	Only sub	Full	Only sub
	IRLS	IRLS	IRLS	IRLS
	1	2	3	4
Sub	-0.083		-0.114	
	(0.376)		(0.299)	
Sub*Optional_Horizontal	0.931***		0.687***	
	(0.312)		(0.254)	
Optional_Horizontal		0.856***		0.830***
		(0.295)		(0.245)
No. of subcontractors		-0.046		0.053
		(0.082)		(0.063)
Value of subcontracts		0.187		0.292**
		(0.138)		(0.137)
Bidder-subcontractor		-0.090		
		(0.191)		
Res.price/Exp.dur./No.part.	YES	YES	YES	YES
Category of work dummy	YES	YES	YES	YES
Type of auction dummy	YES	YES	YES	YES
Type of CA dummy	NO	NO	YES	YES
Firm size dummy/Cons.	YES	YES	YES	YES
Year dummy	YES	YES	YES	YES
Observations	226	180	514	396

Note: See Appendix A for definition of variables.
*** p<0.01, ** p<0.05, * p<0.1.

In the model specifications estimated in Table 7 columns 2 and 4, we include certain aspects of subcontracting (e.g. the number of subcontractors and the proportion of work contracted out) to investigate whether they are discounted in the bidding rebates and might influence the validity of our estimates. In particular, to address this possibility, we added two variables to our benchmark model specification for each project, i.e. the number of subcontractors (*No. of subcontractors*) and the value of the subcontracts (*Value of*

to have more weight in the former. OLS estimations confirm similar results and are available on request.

subcontracts). The estimation results show that the coefficients estimated for the *No. of Subcontractors* and the *Value of subcontracts* did not differ significantly from zero, confirming that for a winning bidder to establish more subcontracting relationships with other firms is not necessarily a cost per se.[24] Instead, the effects of these relationships probably relate to their optional horizontal or mandatory vertical format status, and the consequent bargaining positions of the firms involved.[25]

4.2 Looking for the counterfactual: matching estimation

In this section, we propose an alternative estimation of the difference of winning rebates between projects won by firms in optional horizontal subcontracting position and firms in mandatory vertical position. In particular, we apply a propensity score matching (see, Rosenbaum and Rubin, 1983) to evaluate the effect of firm's 'full qualification' (treatment), or optional horizontal subcontracting position, on the winning rebate. The propensity score allows us to consider the firm's probability of receiving the treatment conditional on (observable) auction's characteristics. In our analysis, fully qualified firms in optional horizontal subcontracting position constitute the treatment group, while partially qualified firms in mandatory vertical subcontracting position are the control group. To understand whether there is a difference between the two, we can apply the Average Effect of Treatment on the Treated (ATT, see Becker and Ichino, 2002).

The observed winning rebate (outcome) of contracts won by mandatory vertical firms can be used to estimate the counterfactual outcome of projects won by optional horizontal firms, however, three assumptions of ATT approach have to be met. First of all, we need to satisfy the assumption on balancing of observable variables, which means that obser-

[24]Note that, in column 2 of Table 7, the coefficient for the *Bidder-subcontractor* variable (concerning the presence of at least one subcontractor who also took part as a bidder in the same auction) was not statistically significant.

[25]Note also that, although the public procurement market in Valle d'Aosta is quite small, we rarely saw repeated interactions between contractors and subcontractors. On average, they came together only 1.2 times in a decade. Our results are therefore unlikely to be affected by any advantages derivable from repeated interactions (i.e. a more efficient reduction of the transaction costs, implicit incentives, etc., as mentioned by Marion and Gil, 2012).

vations with the same propensity score have the same distribution of observable auction characteristics independent of the subcontracting position of the winning firm. Secondly, we need to satisfy the unconfoundedness property, which assumes that, conditioning on observed auction characteristics, optional horizontal subcontracting position is independent of the winning bid for cases of mandatory vertical position. Finally, the common-support condition has to be met, that is for each auction won by optional horizontal firm or treated unit, there are mandatory vertical winning firms or control units with similar observable auction characteristics.

In our context, the treatment could not be random and certain types of projects could be more likely to be won by optional horizontal firms than other types of projects. We control for this non-random assignment by matching projects won by optional horizontal and mandatory vertical firms using a set of auction characteristics (such as reserve prices, expected duration of works, category of works dummy, type of CA dummy, year dummy) and we also ensure that the balancing property is satisfied while estimating the propensity score.

Table 8: Descriptive statistics:
optional horizontal vs mandatory vertical projects

Variable	Optional horizontal	Mandatory vertical	
	Mean	Mean	difference
Winning rebate (%)	16.792	14.555	2.237***
Reserve price (Euros)	897328	1079458	-182130**
Number of participants	52.466	35.792	16.674***
Expected duration (days)	302.589	354.443	-51.854***
Road works	0.370	0.309	0.061*
River and hydraulic works	0.236	0.047	0.189***
Buildings	0.121	0.053	0.068**
Regional Gov.	0.619	0.476	0.143***
Municipalities	0.312	0.430	-0.118***
Obs.	365	149	

Note: See Appendix A for definition of variables.
*** p<0.01, ** p<0.05, * p<0.1.

Before showing the results of ATT estimation, in Table 8, we report summary statistics of auctions/projects characteristics comparing the sample of contracts won by optional horizontal firms and that won by mandatory vertical firms. For the following analysis we use the sample of contracts awarded by several CAs in the territory of Valle d'Aosta (514 contracts). Descriptive evidence show that there are differences in terms of auction/project characteristics between contracts won by the two different types of firms. In particular, project won by optional horizontal firms seem to have a smaller size and a shorter in terms of expected duration of days for the execution (i.e., they seem to be less complex), and to have higher number of participants.

Furthermore, we should underline that the 'lottery-like' awarding mechanism in Italian public procurement auctions (see Appendix B) helps us to support the randomness of the treatment: in fact, as previously underlined, the winner firm in the auction depends both on the number and distribution of bids, and the probability of winning conditional on the participation rate is similar to both optional horizontal and mandatory vertical firms.

On this sample of contracts, we estimate the propensity score using probit estimation and, in Table 9, we report the effect on winning rebate when the winning firm has a optional horizontal subcontracting position. Estimation results show that using kernel matching and radius matching (with radius=0.005) estimators, the effect is positive and statistically significant.

Table 9: Matching estimation using winning rebates

	Winning rebate: Oth. PA projects			
Matching estimator	Treatment (n)	Control (n)	ATT	t-stat
Kernel matching	339	137	1.209	2.127
Radius matching (r=0.005)	339	137	1.294	2.518

Statistics based on boostrapped (500 replications) standard errors.

5 Conclusion

We empirically investigated a public procurement setting where existing regulations on firms' pre-qualification affect subcontracting and give rise to two situations: (i) the firm may choose either to subcontract a part of the project horizontally or to complete the works on its own (optional horizontal subcontracting); or (ii) the firm is obliged to vertically subcontract a part of the works (mandatory vertical subcontracting). We considered the two cases in the Italian market for public contracts using data on the firms' qualifications to bid for them. Our aim was to capture the influence of the two subcontracting formats on the value attributed by the bidders to the contract; to do so, we analyzed the bids made at auctions for awarding public contracts, correlating them with each bidding firm's subcontracting status.

The main contribution of this study has been to provide empirical support for different forms of subcontracting originating in public procurement contracts. We found that bidders in a position to choose whether or not to subcontract works horizontally offered larger price reductions than those having to subcontract part of the project vertically. This empirical finding recalls the Spiegel's (1993) theoretical result on horizontal subcontracting which highlighted, under mild assumptions, that this type of outsourcing makes it possible to contain production costs. Our analysis empirically tests this hypothesis in a public procurement setting where firms' production costs - as reflected on their bidding strategies - can be compared in the light of their subcontracting options (i.e., optional horizontal subcontracting *vs* mandatory vertical subcontracting).

Our findings were confirmed when different estimates and different robustness tests were run. In particular, when we focused only on the bids made by winning firms that subsequently subcontracted a part of the works, we found that actually engaging in horizontal subcontracting coincided with lower costs of completion of the contract than when vertical subcontracting was involved. We interpret these findings as follows. Having the option to use subcontractors induces firms to do so only when it is profitable and puts them in a stronger bargaining position when contracting out a part of the works. Firms obliged to

engage in vertical subcontracting lack these advantages.

Our analysis suggests that subcontracting could be an important tool for improving production efficiency and, in such a regulated public procurement market, requirements affecting a contractor's production planning strategy should be carefully designed to avoid negative fallouts on the firms' efficient choices. Further empirical investigations are needed to estimate the effects of different rules on bidders' qualification/screening on subcontracting and on the associated efficiency in production, particularly in public procurement where cost-saving subcontracting could often determine a direct benefit for the community (i.e.: lower execution price).

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Appendix A: Variables, definitions and abbreviations

***Rebate* (or percentage price reduction or discount)** The price cut offered by participants in an auction, expressed as a percentage of the auction's reserve price.

Optional_Horizontal A dummy variable taking a value of 1 if the firm can choose whether or not to horizontally subcontract part of the contracted works; this firm is fully qualified to complete the project alone but it can opt to subcontract part of the works to firms with similar qualifications. The dummy takes a value of 0 if it is required by law to subcontract part of works (that it is not qualified to perform).

Mandatory_Vertical A dummy variable taking a value of 1 if the firm is required by law to subcontract part of the works; this firm does not have all the qualifications to complete the project and it is required by law to subcontract the works for which it is not qualified to firms that hold the required qualifications. The dummy takes a value of 0 if the firm can choose whether or not to subcontract part of the works (being fully qualified to handle them all).

Reserve price The auction's starting value (in Euro) decided by the contracting authority - CA (all the projects considered here had a reserve price higher than 150,000 Euro).

Expected duration The expected duration of the works (in days), decided by the contracting authority - CA.

No. of participants The number of bidders participating in an auction.

Firm size A set of dummy variables used as proxies for the size of bidding firms. Since we do not have data on the number of their employees or their total assets, we constructed proxies based on the type of business entity (there is a positive correlation between Italian firms' business entity and their size). In particular, our proxies were defined as: *Small* (one-man businesses, limited and ordinary partnerships); *Medium* (limited liability companies); or *Large + cooperatives* (public corporations and cooperatives).

Consortia A dummy variable taking a value of 1 when it refers to a temporary association of firms, or 0 otherwise. Firms can join forces, pool their qualifications and form a consortium to participate in a given auction, so we assumed that optionality takes a value of 1 for consortia.

Type of auction A set of dummy variables describing the auction mechanism. *Average price* is an average price auction defined as follows: given the distribution of all the bids for a tender, after excluding the bids in the first and last deciles, the winning bid is the one just below an anomaly threshold value given by the sum of the average bid (simple average of the bids not excluded) and the average deviation of the bids above the average bid. *Average price+lottery* it is an average price auction defined as follows: given the anomaly threshold value calculated as above, the winning bid is the one closest to the mean value between the anomaly threshold and a value obtained by the awarding committee among nine equidistant numbers ranging from the lowest allowable bid to the bid just below the anomaly threshold (disregarding both bids).

Category of work A set of dummy variables representing the main category of works in a project (i.e. road works, buildings, hydraulic works, etc.).

Sub A dummy variable taking a value of 1 if the winning firm subcontracts part of the works in a project, or 0 otherwise.

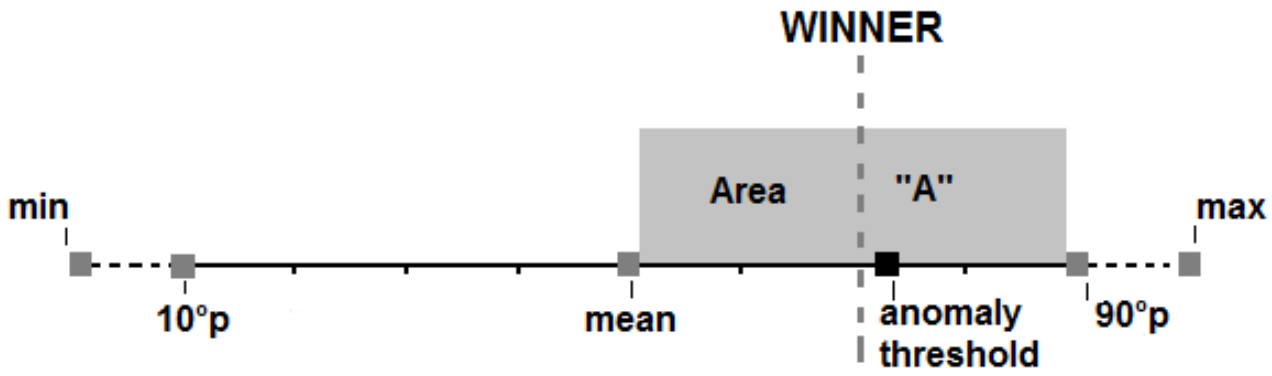
No. of subcontractors The number of subcontractors working on a project.

Value of subcontract The value (in Euro) of the subcontracts for a project.

Bidder-subcontractor A dummy variable that takes a value of 1 if, for a given contract, at least one subcontractor participated as a bidder in the auction. It takes a value of 0 otherwise.

Type of CA A set of dummy variables representing the type of contracting authority auctioning the works (regional or local governments, public health authorities, etc.).

Appendix B: Awarding mechanism: average price



The average price mechanism can be briefly described as follows: given the distribution of all bids received, the bids located in the first and last deciles are excluded and the winning bid is the one immediately below an anomaly threshold resulting from the sum of the average bid (the simple average of all not-excluded bids) and the mean deviation of the bids above said average bid.