UNIVERSITÀ DEGLI STUDI DI PADOVA

Dipartimento di Scienze Economiche ed Aziendali "Marco Fanno"

SUBCONTRACTING IN PUBLIC PROCUREMENT: AN EMPIRICAL INVESTIGATION

LUIGI MORETTI
University of Padova

PAOLA VALBONESI
University of Padova

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Subcontracting in Public Procurement: an Empirical Investigation*

Luigi Moretti
University of Padova

Paola Valbonesi
University of Padova

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Abstract

We have assembled a new dataset and we have empirically investigated the effects of subcontracting on the bidding price in auctions for the awarding of public contracts in Italy. The required qualification for firms aiming to bid for Italian public contracts determines different subcontracting formats: according to 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" subcontracting. The latter are free to choose whether or not to subcontract some tasks to similarly qualified firms, adopting an "optional" subcontracting. We find that firms in a position to choose whether to subcontract or not generally offer lower prices than those firms which must proceed with mandatory subcontracts. This result, which holds true after controlling for auction characteristics, firms' fixed effects, and characteristics of the subcontract, indicates that firms apply different prices to different subcontracting strategies in the public procurement supply chain.

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Keywords: regulations for subcontracting in procurement, firm's supply chain strategy, public procurement, horizontal (and vertical) subcontracting.

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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. Many theoretical contributions have addressed the determinants of subcontracting *vs* vertical integration - and, more generally, of firms' boundaries - referring to transaction costs (Williamson, 1985), property rights (Grossman and Hart, 1986) and knowledge-based view of the firm (Kogut and Zander, 1992 and 1996). Empirical research has provided several case studies which documented how and when firms adopt subcontracting to efficiently organize production in different economic sectors.[1]

Both these theoretical and empirical contributions are based on the firm's *independent* choice of internal/external sourcing. Differently, in public procurement, firms are often constrained by many rules directly regarding their internal organization. What decisions should the firm be allowed to take in production planning to execute a public procurement contract efficiently? The answer to this question should impinge on the decision makers' design of public procurement procedures. In particular, it could reduce the adoption of rules which make public procurement cumbersome as they negatively affect the firm's efficient supply chain and, in turn, increase the average price that the public body has to pay.

Typically, the regulatory burden affecting subcontracting choice in the execution of public contracts can be explained by two main factors. First, public resources conveyed through these procurement contracts are often specifically intended for affirmative actions (i.e., programs indirectly encouraging the participation of disadvantaged businesses by means of subcontracting schemes). Second, highly regulated procedures are set for the award and management of these contracts in the need to prevent favoritism, corruption and poor-performance.[2]

Concerning the former, 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) examines one such DBE program implemented by the California Depart-

[1] See, among others, Novak and Stern (2008) and Macher (2006), investigating outsourcing in the automobile and semiconductor industries, respectively; for a thought discussion on core competencies and activities which are better performed externally, see Quinn and Hilmer (1994).

[2] In a recent contribution, Spagnolo (2012) highlights the cost of reduced discretion for the public buyer and discuss the role of reputation, competition and entry in the context of public procurement.

ment of Transportation, finding that the average price of items on state-funded contracts fell by 5.6 per cent after this affirmative action was abandoned. Conversely, De Silva et al. (2012) look at a DBE program adopted in Texas and find no differences in bidding prices between projects with and without such affirmative goals.[3]

As for the latter, no empirical work has yet investigated how procurement regulations preventing supplier's poor performance affect his make-or-subcontract decision and, in turn, determine the effectiveness of supply-chain management in public contract.[4] This is surprising, considering that public procurement accounts for about 15 percent of the GDP in developed countries: such big business deserves a clear understanding of which rules are best to ensure that contractors are in the right condition to make efficient supply-chain decisions.[5]

This paper. This paper aims to contribute in filling the gap, specifically investigating the effects of the Italian regulation concerning the firm's entry and make-or-subcontract decision in public procurement (the so called "qualification system" in public procurement). As occurs in other national settings, this Italian regulation requires i) that firms undergo a preliminary qualification process before they enter the public contract market and ii) that every task in public contracts be completed by such qualified firms.[6] Specifically, these requirements affect the firm's make-or-subcontract decision in two ways, as follows:

- First, *if the firm is not qualified to complete all the tasks involved in a given contract*, its production strategy has to take into account a "mandatory subcontracting" agreement with another firm which is qualified to do so.

- Second, *if the firm is fully qualified for all the tasks involved in a given contract*, its production

[3]Marion (2009) exploits 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 is 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.

[4]Conversely, a conspicuous number of empirical contributions have investigated which auction format should be addressed by procurement regulation to reach the lower awarding price and the better contractual performance. See, among others, Bajari et al. (2009), Cameron (2000), Decarolis (2012), Bucciol et al. (2011), Lewis and Bajari (2011), Olivares et al. (2012).

[5]The recent "Green Paper on the modernization of EU public procurement policy" (2011) points out that subcontracting is a relevant tool to encourage SMEs participation in public procurement contracts, whereby SMEs are considered of crucial importance for stimulating job creation, economic growth and innovation. However, no hints for best practices are provided.

[6]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).

strategy may, or may not, involve subcontracting a part of the work to a similarly qualified firm; in this case, the firm holds an "optional subcontracting" position.

Thus, qualified firms bid for each tendered public contract, knowing in advance their mandatory - or optional subcontracting position.[7] Our aim is to test if these subcontracting positions - belonging to the existing regulatory framework - are likely to differ in terms of the firm's bid.

The data. We have assembled an original database containing information about Italian public procurement contracts awarded by means of open tenders and about characteristics of bidding firms. Specifically, for each tendered contract we have collected all the tasks to be completed (i.e.: the "categories of work" corresponding to the qualifications required), the identity of each bidding firm and its qualifications held. Thus, matching the qualifications required to execute the contract with each bidder's own qualifications, we are able to identify the bids offered by partially-qualified firms (that will have to engage in mandatory subcontracting if they win) and those by fully-qualified firms (that may choose to complete the works alone or to subcontract a part of them).

Our results. Adopting a reduced form approach and checking for auction-/contract-related characteristics and firms' fixed effects, we have found that bidding firms in a position to choose whether or not to subcontract a part of the work (i.e., optional subcontracting), offer lower prices than those obliged to subcontract a part of the work (i.e., mandatory subcontracting). This effect is still significant when we focus on the sub-sample of bids offered by the winning firms that *actually* did engage in subcontracting.

These results indicate that the production efficiency deriving from subcontracting is higher when, for the firm concerned, it is an option - and not an obligation - to perform activities externally.[8] In other words, mandatory subcontracting, an induced practice which restricts the firms' supply-chain, tends to increase procurement performance costs.

We find the explanation for these results in the interplay of different factors as follows. If a firm can choose to subcontract, it will do so only if it is profitable. In this case, subcontracting also implies outsourcing a part of the works to "similar and known" firms and this entails lower search

[7] An interesting study on the effects by costly ex-ante or ex-post qualification in procurement has been recently proposed by Wan et al. (2012): these authors provide an analytical model on the buyer's optimal strategy in designing the qualification as combined with a reverse auction, and then test their results in the lab.

[8] In a competitive stochastic investment game, Van Mieghem (1999) investigates the firm's choice of subcontracting as an option value, finding that it improves its financial performance and coordination on investment in presence of high degree of uncertainty. Atamturk and Hochbaum (2001) study subcontracting as an alternative to directly acquiring capacity or holding inventory to satisfy nonstationary demand over a finite horizon.

costs as well as a greater information symmetry concerning the execution costs. Moreover, 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 optional than in mandatory subcontracting transactions.

Related Literature. Our results mainly contribute to two strands of literature. First, to the empirical literature on public procurement which widely investigates how to reach both cost efficiency and optimal performance, addressing issues in the awarding and management phases.[9] Here, subcontracting has only recently attracted attention. As discussed above, De Silva et al. (2012) and Marion (2009) focus on programs supporting subcontracting in favor of specific groups of firms and their effects on prices. Miller (2010) considers the impact of complexity and incompleteness of construction contracts on subcontracting *vs* in-house arrangements. Gil and Marion (2012) examine the effect of past and future relationships between contractors and subcontractors in enforcing informal agreements. None of these papers, however, provide an empirical analysis on procurement pricing when regulatory rules aiming to prevent contractor's poor performance affect firm's subcontracting decision, as we do here.

Second, our empirical results also contribute to the extensive academic debate on a firm's boundaries: in this respect, we offer an empirical evidence on "horizontal subcontracting", a form of external sourcing that has been investigated by a few theoretical papers.[10] Among these, in a two-firms Cournot-setting with asymmetric and strictly convex cost functions, Spiegel (1993) shows that horizontal subcontracting improves productive efficiency on the one hand, and it softens competition, on the other.[11] The Spiegel's paper also analyzes the order in which the quantity and the subcontracting choices are set: ex-ante horizontal subcontracting - i.e., both the firms sign an agreement *before* they compete in the downstream market - improves welfare, and there could be

[9] In this strand of literature, highway procurement data are largely used: Lewis and Bajari (2011) investigate the effectiveness of time incentives in auctions; Bajari et al. (2006) and Miller (2010) study the cost of incomplete contracts; Gil and Marion (2012) investigate how future interactions are used to enforce informal contracts; Krasnokutskaya and Seim (2011) study bid preference programs; Marion (2012) analyzes horizontal subcontracting.

[10] Kamien et al. (1989) study horizontal subcontracting in a Bertrand setting, where two firms with convex costs, first compete to win a contract, then have the chance to use subcontractors. This study shows 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. Gale et al. (2000) study sequential procurement and horizontal subcontracting in a setting where two symmetric sellers with non-constant-marginal-costs are approached by fragmented buyers and selected by a second price auction.

[11] Recently, Marion (2012) - in the context of auctions for California Department of Transportation highway repair contracts - empirically disentangle these two effects, finding that productive efficiency is a primary motivation for horizontal subcontracting.

a similar effect in ex-post subcontracting as well, provided the efficiency gains from production are sufficiently large.

Referring our empirical analysis to the Spiegel's theoretical one, the optional subcontracting in our setting corresponds to the *horizontal* subcontracting addressed in Spiegel's model, i.e. an agreement between rival firms, "each of which is capable of producing and marketing its product independently" (Spiegel, 1993). Our empirical results confirm the Spiegel's finding that horizontal subcontracting promotes productive efficiency as compared - in our setting - to mandatory subcontracting, i.e., a form of required vertical outsourcing.[12]

The structure of the paper. The remainder of this paper is organized as follows. Section 2 describes the institutional features of public procurement auctions and subcontracting in Italy. Section 3 gives detailed information on the datasets on which we have based our investigations. Section 4 presents the econometric model, the empirical results and the tests performed on their robustness, considering all the firms' bidding price reductions. Section 5 illustrates the results of our estimations focusing on the rebates offered by the winning bidders, i.e. the firms that won and fulfilled the contract. Conclusive comments are given in Section 6.

2 Regulation on entry in the Italian procurement for public works

In this section we briefly present regulations on supply and demand sides of the Italian market for public procurement works, focussing on those rules which directly affect the firm's subcontracting decision.

The supply side. According to the Italian law on public procurement, firms must be qualified to bid in auctions for public work contracts worth more than 150,000 euros.[13] The Italian system for qualifying firms is operated by a third part (i.e.: actually, 37 private companies, called SOA) accredited and monitored by the AVCP,[14] the authority in charge of regulating the national market for public works, supplies and services. The firms' qualifications are provided once established

[12] Indeed, in our setting, optional subcontract corresponds to a situation in which the firm can choose to delegate part of the works to similar qualified firms (horizontal subcontracting); mandatory subcontracting corresponds to an unavoidable agreement between firms with complementary capabilities/assets with a view to obtaining a final output - vertical subcontracting (Webster et al., 1997).

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

[14] "Autorita' di Vigilanza sui Contratti Pubblici di Servizi, Lavori e Forniture".

"general" and "technical" requirements have been ascertained by one SOA. The former are requirements concerning the firm's financial standing and criminal records (e.g., anti-Mafia); these are the same for any firm wishing to participate to an auction for the procurement of a public work. The latter requirements have to do with the specific technical skills needed to perform certain works and are usually assessed on the firm's documented expertise and observable items. Specifically, in the Italian public works have been defined 46 "categories of works" over which firms can accordingly get qualifications. The qualification for each category and size (i.e., value) of work is a costly process for the firm (i.e., different fees for different categories of works/size), and remains valid for 3 or 5 years, after which must be renewed.

The demand side. A large part of the Italian public procurement market consists of contracts typically awarded by local CAs (i.e., municipalities, provinces, regions).[15] In awarding the contract, the CA should specify all the tasks (i.e., the categories of works) involved in the project and distinguish which is the *main* category from which are the *secondary* categories of work included in the project. For example, consider a contract for the building of a road in a new residential area; the fulfilment of this contract contains three tasks: t_A (road works), t_B (water works), t_C (sewage works). Accordingly, in the requests for tenders, the CA will present the former task t_A as the *main* category of work and the remaining two (t_B and t_C) as *secondary* categories of work. This distinction is relevant as participation in tenders is restricted to firms qualified for the *main* work category.[16] Alternatively, firms that lack this qualification can participate as part of temporary consortia (called "Associazioni Temporanee d'Impresa", ATI): these consortia are created *ad hoc* to bid for a given contract, and involved at least one firm fully qualified for the main task.[17]

For the *secondary* categories of works involved in a public contract up for tender, the bidding firm may either be qualified or not. 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, giving the rise to an optional subcontracting). On the other hand, if a firm is not qualified for one (or more) of secondary categories, it

[15] According to the last AVCP Annual Report, about 63 per cent of contracts in 2011 have been awarded by local governments for a value of 1,160 million euros.

[16] 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 subcontracting according to our definition.

[17] 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 tendered contract.

can still bid for the contract but will have to declare it will subcontract the works for which it lacks qualification to qualified firms; and if it wins, it is required to subcontract (i.e., mandatory subcontracting).[18]

Considering optional and mandatory subcontracting in terms of firms' asset, the former can be seen as a horizontal outsourcing since it occurs between two similarly qualified - rival - firms; the latter corresponds to a required vertical outsourcing as it occurs between two firms with complementary capabilities.

To summarize. The aim of the Italian system regarding firms' qualification is to restrict the participation to the call for bids to firms capable of executing efficiently the *main* category of contracted works (i.e., which result officially qualified to this effect). For the *secondary* categories of works involved in the tendered project, firms may, or may not, be fully qualified: in the latter case, firms are obliged to subcontract the works to qualified firms, since all aspects of the project involved must be handled by firms qualified to do so.

A noteworthy direct consequence of this regulation of the public procurement market is that, when a contract is tendered - since the categories for which bidding firms should be qualified are there announced - the potential position of each bidder concerning any subcontracting is well defined. 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. Thus, the regulation on qualification for bidders to public contracts allows firms' assessment of their own production strategy at the bidding stage: this permits us to observe the two subcontracting formats and, accordingly, the firms' bids. For the sake of our analysis, it is important to bear in mind that, within the framework that we have investigated, the same bidder may be in a position to consider optional subcontracting for some contracts, while being obliged to mandatory subcontracting in others.

[18] As a remote alternative, the firm can lease the qualification it lacks from a qualified firm that is not bidding for the contract: this is a rarely used practice because it entails a very expensive agreement (called "avvalimento").

3 Data

Different sources of data were used to assemble our original dataset for the purposes of the present analysis. Detailed information on each open tendered public contract have been taken from a hitherto unexploited dataset, collecting transcripts of competitive auctions conducted from 2000 to 2009 by the Regional Government of Valle d'Aosta.[19] 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 on the tendered contract from a national dataset managed by the AVCP, containing all the contracts with a reserve price higher than 150,000 euros: this dataset includes information on the contract awarding procedure, the exact value of the contract, and the categories of works involved.

Information about the firms' qualifications was extracted from another national AVCP dataset known as the "Casellario SOA", a sort of national register collecting - for each work category - the qualifications status of each bidder.

Summing up, for each tendered contract, we have information on all the qualifications required to complete the tasks involved in the contract and all the actual qualifications hold by each bidding firm. Matching these data enabled us to identify the bidding firms that would have the option to subcontract and those which would be obliged to proceed with a mandatory subcontract for part of the works.

Our dataset consists of public contracts awarded by a local Contracting Authority (henceforth, CA) by means of open tenders, where firms participate by offering a price (i.e., a percentage reduction on the reserve price set by the CA).[20] Once the CA has verified the bidders's legal, fiscal, economic, financial and technical requirements, the contract is awarded according to the rules governing the competitive auction.[21]

[19] Valle d'Aosta is a small mountainous region (3,263 sq. km, 951 MSL) with a population of 129,000 on Italy's north-western borders with France and Switzerland.

[20] According to EU directives, in Italy public procurement can take place through four types of awarding procedures: open, restricted, and negotiated procedures, and competitive dialogue. In our study, we consider only those 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.

[21] We have the details for all the public contracts awarded by means of open tenders in the form of average-price auctions from 2000 to 2009 by the Valle d'Aosta Regional Government. 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; 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.

Table 1: Descriptive statistics: characteristics of auctioned contracts

Bid-level data					
Variable	Obs.	Mean	St.Dev.	Min	Max
Bid (Rebate, in %)	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.

Our dataset covered 269 auctions for public contracts, for which a total of 13,317 price offered by bidders consisting of 891 firms and 1,777 temporary consortia. The average reserve price (i.e., the price set by the CAs on the contracts awarded) was approximately 1.1 million euros (ranging from a 155,000 to 5.2 million euros). In terms of tasks, as shown in Table 1 where further summary statistics are also included, these contracts refer mainly to road works (37.2%), river and hydraulic works (29.7%), and special structural works (7.8%).

As shown in Table 2, 73.8% of the bids in our sample were offered by firms that had all the qualifications required (so they could opt to horizontally subcontract a part of the works if they wished), while 12.8% by firms that were not qualified for some of the secondary categories of works (and they would consequently be obliged to subcontract them to other qualified firms). Finally, about 13.3% of the bids 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 whether to subcontract or not, and about 1.4% would always have been committed to adopting the mandatory subcontracting.

See Figure 1 in Appendix B for an illustration and Decarolis (2009) for a discussion of the average price mechanism. In the setting we investigated, 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.

Table 2: Descriptive statistics: bidders' characteristics

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

See Appendix A for definition of variables.

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 offered, 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.

4 Analysis of the bidding offers

4.1 Testable hypothesis and model specification

In this section, we will consider the bids offered by all the participating firms in the 269 auctions for public procurement contracts. In many contributions to the literature on public procurement studying contracts awarded by means of reverse auctions, bids are investigated because they represent the value attributed by the firm to the project, i.e. what the firm expects it will cost to complete the works, plus a mark-up. Accordingly, in this study, we simply assume that bid is a proxy for each firm's costs of completing the tendered contract.

As discussed earlier, mandatory and optional subcontracting in this procurement setting can be considered - respectively - as a planning constraint or a planning tool in the firms' production strategy, with consequently different effects on expected costs and, therefore, on the firms' bids. Our testable hypothesis is that there might be a significant difference in the price offered (i.e., expressed as a percentage rebate on the reserve price set by the CA) between firms obliged to subcontract and those in a position to decide whether to complete the contracted works alone or outsourcing part of them.

A simple two-group mean-comparison test (Table 3) shows that the average rebates offered by firms obliged to subcontract were significantly lower (i.e., their prices were higher) than those offered by firms which could proceed with optional subcontract; the picture does not change after excluding the consortia from the sample.

Table 3: Correlation: Subcontracting format and bidding rebates

	Average bid	Average bid (excluding consortia)
Optional	17.35	17.34
Mandatory	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 offered by bidders in different subcontracting roles, we estimated the following model specification for bidding rebates:

$$Rebate_{ij} = \alpha + \beta Optional_{ij} + \gamma Q_j + \theta X_i + \epsilon_{ij}. \quad (1)$$

where *Optional* is a dummy variable with a value of 1 when the firm i is fully qualified to handle the project j's tasks (i.e., in the position of optional subcontracting), and a value of 0 if it is partially qualified (i.e., in the position of mandatory subcontracting). Q_j is a set of variables to control 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),[22] and ϵ_{ij} is the error component.

To reduce the omitted variable problems, in some specifications, we also included firm's fixed effects to adjust for firm-specific characteristics (e.g., size, productivity, financial position, and location): this enabled us to focus on the within-firm variation in optional or mandatory 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 included firm-year fixed effects.

4.2 Estimation results

Our primary coefficient of interest is β, which indicates whether a firm's subcontracting status influences its bidding offer. This coefficient reflects the difference between the rebate offered by firms that can choose to subcontract vis-a-vis those obliged to subcontract. To deal with the potential heteroschedasticity issues, we use ordinary least squares (OLS) estimates with robust standard errors, clustered at firm level (to enable within-firm observations to be correlated).

Our results are given in Table 4, columns 1-3: they show that the coefficients for the *Optional* 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 as they wish) offer significantly greater rebates than firms that would be obliged to subcontract out a part of the works to other qualified firms. 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 results a binding requirement.

We interpret our findings as relating to the following considerations. If a firm can choose to

[22] 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.

subcontract, it will do so only if it is profitable.[23] Optional 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 than any form of required subcontracting to firms with "different and complementary" qualifications. Moreover, 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 optional than in mandatory subcontracting.

Table 4: Estimation results: bidding offers

Dependent variable:	Bidding Rebate		
Mean outcome:	17.21	17.15	17.23
	OLS	OLS	OLS
	1	2	3
Optional	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.

These considerations are based on several studies on the effect of parties' information asymmetry and bargaining power on the outsourcing choice. As for the effects from information asymmetry, Lewis and Sappington (1991), in a standard procurement model, assume that the firm is better able to monitor effort internally rather than under outsourcing. Because the subcontractor may have a lower cost technology, they argued that the decision of outsourcing belongs to a trade-off between

[23]Quinn and Hilmer (1994) present an extended discussion about the firm's relative risks/costs and benefits in outsourcing.

lower production cost and higher monitoring cost: thus, a contractor opts to use subcontractors when the latter's efficiency is greater than the former's loss of control associated with outsourcing. In our setting, monitoring costs are lower for optional subcontracting than for mandatory subcontracting, as in the former part of the work is delegated to similar qualified firms.[24]

As for the effects from bargaining power, Grossman and Helpman (2002) investigate how the distribution of bargaining power between the supplier and the final-good producer (i.e., respectively the subcontractor and the firm, in our setting) affect the viability of outsourcing: their model shows that a generic task - as opposed to a specific one - enhances outside options which improves the task producer's bargaining power. Similarly, in our setting, the firm which can choose whether to delegate part of the works (i.e., optional subcontracting) is endowed with an outside option which enhances its bargaining power in outsourcing; this outside option is not present in the case of mandatory subcontracting.

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. It is hardly surprising that the rebates 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).[25]

As for the other characteristics of the firms, the model specification in column 1 of Table 4 includes dummy variables for the firms' size. The model in column 2 includes dummy variables for firm-related fixed effects that enabled us to control 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 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

[24] Riordan and Sappington (1987) provide a two-stage production model where costs are observable only by the producing party: information asymmetry between parts and correlation between first- and second-stage costs determine the principal's optimal choice in the organization of tasks' production.

[25] In the US, Bajari et al. (2009) show 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) find that a larger number of bidders increased the amount of the winning bidder's rebate. Concerning the effect of the reserve price, our results confirm its positive effect on the rebates offered, as reported by Coviello and Gagliarducci (2010), and Decarolis (2009). Bucciol et al. (2011) also find that works that were expected to take more time are associated with bidders' higher rebates.

sample, concentrating only on the bidding firms that were fully qualified for some auctions and partially qualified for others. This is important for two reasons: first, 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); second, and more importantly, it supports our inference that the overall results were uninfluenced by those firms that always or never had all the required qualifications, thus allowing us to capture the with-in firm (or with-in firm-year) variation in subcontracting status.

4.3 Robustness checks

A first concern regarding our estimates has to do with the influence of extreme bids. In fact, it may be that outlying bids drive the estimation of the coefficient of our *Optional* 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 (Verardi and Croux, 2009). As shown in Table 5, column 1, the estimated coefficient indicates that a firm's optional 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 bids offered by firms in mandatory and optional 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 rebates 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 the price offered.
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' rebates. In particular, we distinguished the area around the winning rebate as follows (see Figure 1 in Appendix B): the winning offer in each auction was included between the mean rebate 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. This is because one might suspect that previous results are driven by the fact that bidders liable to mandatory subcontracting tend to offer particularly small rebates, i.e., on the left-hand side of

the distribution. If this were true, we would expect two situations. First, subcontracting status might not be the only difference between the two types of bidders (i.e., between firms that might opt for optional subcontracting and those obliged to subcontract some of the works), there might be other differences relating to their productivity and technology. Second, firms bidding in a mandatory 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).[26] Therefore, we concentrate our analysis on "area A". Then, after having made sure that the subcontracting format is not a significant determinant of the bidders' likelihood of offering bid in "area A" of the auction-specific distribution, we nonetheless find that the difference in the rebates offered in the two different subcontracting conditions persisted and was still statistically significant (Table 5, column 2). Thus, even when we only consider the bidders in a given auction that offered rebate coming closer to the winning one ("area A"), the advantageous position of the firms that could opt for optional subcontracting seem to be reflected in the rebate offered.

Finally, we perform a test to estimate the probability of very high rebates being offered for a given auction. In fact, if firms with an optional subcontract status are in a better position than those required to proceed with mandatory subcontract, then we should see the optionally subcontracting bidders offering very high rebates. After appropriately taking firm-specific characteristics into account, in Table 5, column 3, we estimate the probability of rebates beyond the winning bid being offered at a given auction.[27] The coefficient for the *Optional* variable is positive and statistically significant using a conditional logit estimation with the firm's fixed-effects.

[26]The analysis of bidders' prices 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 are 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 data for all Italian firms' qualifications. Having included fixed effects allows us to focus on firms that appear to bid in either a mandatory or an optional subcontracting condition and to exploit within firm variation. In addition, we note that the bidders', irrespective of their subcontracting status, are equally likely to bid for smaller and larger projects.

[27]Note that we implicitly also assume that firms do not know how the bids are distributed for a given auction.

Table 5: Robustness checks: bidding offers

Dependent variable:	Bidding Rebate		Pr.(Bid>Win.Bid)
Mean outcome:	17.21	18.70	0.093
Sample:	All bids	Bids [mean, 90' perc.]	All bids
	IRLS	OLS	Cond.Logit(OddsR)
	1	2	3
Optional	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.

5 Analysis of the winning offers

This section studies whether the more aggressive bids offered by firms that can choose whether or not to subcontract belong to expected potential advantage from outsourcing, or due to the fact that such firms will not use subcontractors. To ascertain whether firms' optional subcontracting status is effectively associated with lower prices, we check which of the contract-winning firms that could opt for outsourcing *actually* used subcontractors to complete a part of the project.

With this aim, we consider now two samples: one consists of 226 winning bids drawn from the sample of auctions held by the Regional Government of Valle d'Aosta;[28] the other (which served to test the robustness of our estimates) includes a larger number of winning bids in 514 auctions held by several CAs in the Valle d'Aosta between 2000 and 2009. For each project, we obtain 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).

[28]This sample is extracted from the 269 auctions held by the Regional Government of Valle d'Aosta, for 43 of which we do 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.

Table 6: Descriptive statistics: winning offers and characteristics of contracts

Procurement projects issued by Valle d'Aosta Regional Government					
Variable	Obs.	Mean	St.Dev.	Min	Max
Winning price (Rebate %)	226	17.258	4.359	3.62	31.99
Sub	226	0.814	0.390	0	1
Optional	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	514	0.710	0.454	0	1
No. of subcontractors	514	1.670	1.923	0	17
Value of subcontracts (euros)	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.

For the larger sample of auctions (514), we only know the characteristics of the winning firms and their winning rebate, whilst we have no information on the bids of all the other participants in the auctions and their characteristics.[29] For the smaller sample of auctions (226), the greater amount of information also enable us to account for the possibility of collusive behavior at the auction stage between the successful firm and the subcontractor: in fact, we check whether the subcontractors also participated as bidders in the same auction. This is an interesting check because subcontracting could be used as a way of providing compensation for any collusive agreements between bidders

[29]See the lower panel in Table 6 for summary statistics on this sample. 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. territorial associations for mountainous areas. Note that the smaller set of winning offers for contracts awarded by the Regional Government is a sub-sample of this larger one.

participating to the same auction (or, repeatedly, to different auctions).[30]

Descriptive statistics on the sample of winning rebates on the Regional Government's auctions highlight that there is a slight difference in adopting and managing subcontractors between firms with optional or mandatory subcontracting status. One might argue that the discounted effect of different subcontracting positions on rebates might be influenced by the firms' different probability of using subcontractors. We find, 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 similar chances of winning and, if they won, of using subcontractors.

Finally, it is also noted that the two types of bidder awarded subcontracts for similar proportions of the projects' value (on average about 284,000 euros, i.e. about 1/4 of a project of average size) to subcontractors of similar size (40% of the subcontractors were large firms). When winning firms could opt whether to subcontract, they outsourced to a slightly smaller number of subcontractors (1.8) than when they were required to outsource (2.2), or when they belonged to consortia (2.3).

5.1 Estimation results

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

The results are given in Table 7 columns 1 and 3, showing that the *Sub*Optional* interaction term is positive and statistically significant, telling us that when firms engage in subcontracting, they offer larger rebates when they can choose to do so (optional) than when they are obliged to do so (mandatory). While the effect of subcontracting per se (*Sub*) is not statistically significant.[31]

[30] 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 bidders-subcontractors had offered higher than average rebate, and 54% had offered higher rebates than the winner. Assuming that the bidding rebates 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.

[31] The two different effects of optional versus mandatory subcontracting on the bids may be responsible for the lack of significance of the average effect of subcontracting per se. Also Coviello and Mariniello (2010), analyzing Italian procurement auctions without make a distinction between optional and mandatory subcontracting, find that subcontracting per se is not significantly associated with rebates.

Table 7: Estimation results: winning offers

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	0.931***		0.687***	
	(0.312)		(0.254)	
Optional		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.

These empirical findings recall Spiegel's theoretical results (1993) on horizontal subcontract which highlight that this form of outsourcing allows firms to improve their production efficiency. Horizontal subcontracting corresponds in our setting to optional subcontracting and this, indeed, allows firms to offer higher rebates than firms engaging in mandatory subcontracting (a form of vertical outosurce). In particular, our estimates indicate that a firm's choice to subcontract is a determinant of the benefit they gain from subcontracting: it is the option to subcontract that induces firms to outsource only when it is profitable. This option, in turn, put the firm in a stronger bargaining position than the obligation to contract out a part of the works. This is confirmed by the results in columns 2 and 4 of Table 7, where the two samples of auctions are restricted to contracts where at least some of the work was handled by subcontractors (i.e., the focus in these columns is limited to projects that involve subcontracting). The coefficient estimated for the *Optional* variable is again

positive and statistically significant.[32]

In the model specifications estimated in Table 7 columns 2 and 4, we include two further variables - the number of subcontractors (*No. of subcontractors*) and the value of the subcontracts (*Value of subcontracts*) - to investigate whether they weight in the bids offered and influence the validity of our findings. The estimation results show that the coefficients estimated for the *No. of Subcontractors* are not statistically significant. This result is in line with the non significant coefficient of subcontracting and indicate that the establish of more subcontract relationships do not influence the firm's bid. While, the estimated coefficients of the variable *Value of subcontracts* is positive and in one case (in column 4 of Table 7) statistically significant. This result indicates that, independently of their subcontracting status, firms benefit from outsourcing a large amount of works.[33]

We should also note that our results are unlikely to be affected by any advantage from repeated interactions. In fact, although the public procurement market in Valle D'Aosta is quite small, we rarely observe repeated interactions between contractors and subcontractors: on average, they came together only 1.2 times in a decade. This is in contrast with the empirical findings on number and effects of subcontracting relations by Gil and Marion (2012) in procurement contracts awarded by the California Department of Transportation. Note that the environment analyzed in the Marion and Gil's paper is much different: there, subcontractors have not to be strictly qualified and contractor benefits of larger discretionality in the outsourcing choice; this, in turn, potentially gives the rise to relational intertemporal incentives.

5.2 Looking for the counterfactual: matching estimation

In this section, we propose an alternative estimation of the difference of winning prices between projects won by firms in optional subcontracting position and firms in mandatory 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 subcontracting position, on the winning

[32]To deal with any outliers, we use robust regressions (IRLS, iteratively re-weighted least squares), which iteratively assign a lower weight to deviant observations. The average winning prices are basically distributed in the same way in the two samples; however, when the distribution of the winning price is compared with the distribution of all the prices offered for contracts with the Regional Government of Valle d'Aosta (as discussed in Section 4.1), the presence of outlying observations seem to have more weight in the former.

[33]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) is not statistically significant.

bid. 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 subcontracting position constitute the treatment group, while partially qualified firms in mandatory 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 price (outcome) of contracts won by firms required to proceed with mandatory subcontract can be used to estimate the counterfactual outcome of contracts won by firms in optional subcontracting status. However, three assumptions of ATT approach have to be met. First of all,the assumption on balancing of observable variables has to be satisfied. This means that observations with the same propensity score have the same distribution of observable auction characteristics independent of the subcontracting position of the winning firm. Second, unconfoundedness property has to be met. This property assumes that, conditioning on observed auction characteristics, optional subcontracting status is independent of the winning bid for cases of mandatory position. Third, the common-support condition has to hold, that is for each auction won by optional firm or treated unit, there are mandatory 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 firms than other types of projects. We control for this non-random assignment by matching contracts won by firms with optional and mandatory status using a set of auction characteristics (such as reserve prices, expected duration of works, category of works dummy, type of CA dummy, year dummy). We also ensure that the balancing property is satisfied while estimating the propensity score.

The randomness of the treatment is also supported by the auction mechanism adopted in Italian public procurement auctions. In fact, in these average price auctions, the winner firm depends both on the number and distribution of bids (see Figure 1, Appendix B); and note that the probability of winning, conditional on the participation rate, is similar to firms with optional and mandatory status.

Before showing the results of ATT estimation, in Table 8, we report summary statistics of auction/contract characteristics comparing the sample of contracts won by firms with optional and

that won by firms with mandatory status. 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/contract characteristics between contracts won by the two different types of firms. In particular, project won by firms with optional status have a smaller size and are shorter in terms of contracted duration of days for their execution (i.e., they seem to be less complex); moreover, the auctions for their awarding have higher number of participants.

Table 8: Descriptive statistics: optional vs mandatory projects

Variable	Optional	Mandatory	
	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.

On this sample of contracts, we estimate the propensity score using probit estimation and, in Table 9, we report the effect on winning bids when the winner has an optional 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 offers

	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.

6 Conclusion

We empirically investigated the Italian public procurement setting where existing regulations on firms' pre-qualification affect subcontracting and give rise to two alternative production supply-chains: (i) the firm may choose either to subcontract a part of the contract or to complete the works on its own (optional subcontracting); or (ii) the firm is obliged to subcontract a part of the works (mandatory subcontracting). We consider the two cases analyzing data on auctions for public works and participant bidders characteristics.

We found that bidders in a position to choose whether or not to subcontract part of the contract offered lower prices (i.e., higher rebates on the the reserve prices set by the CA awarding the contract) than those required to subcontract. Our findings were confirmed by different estimates and robustness tests. In particular, when we focused only on the bids made by auctions' winners that subsequently subcontracted a part of the contract, we found that actually engaging in optional subcontracting coincided with lower costs of completion of the contract than when mandatory subcontracting was required. 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 mandatory subcontracting lack these advantages.

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. In our setting, optional subcontracting corresponds to the horizontal one defined by the Spiegel's analysis. Thus, our study provides an empirical test on horizontal subcontracting (i.e., the choice to outsource to similarly qualified firms) as compared to vertical mandatory subcontracting (i.e., the obligation to outsource to complementary qualified firms) in a public procurement setting.

As for policy implications, our empirical result highlights that regulations which restrict firms' supply-chain tend to increase performance costs and this is inevitably captured in higher tendered prices. This is particularly relevant in public procurement where production efficiency by subcontracting influences directly social welfare: the lower price offered by the bidder - correlated with expected costs in delivering the contract - and thus the lower the winning price the CA will have

to pay, the greater the welfare gain for the community.

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 designed to avoid negative fallouts on the firms' efficient choices. Further empirical investigations are needed to estimate the effects of new rules concerning firm's reputation and implicit incentives on subcontracting and on the associated efficiency in production; this is particularly promising in public procurement, a highly regulated setting where cost-saving subcontracting could often determine a direct benefit for the community (i.e.: lower execution price, higher quality in contract performance).

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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 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 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 euros) decided by the contracting authority - CA (all the projects considered here had a reserve price higher than 150,000 euros).

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 an auction, 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 euros) 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

Figure 1: Average price auction