# Evaluation of bidding groups in first-price auctions*

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**Abstract**

We analyze bidding groups in procurement auctions and ask what would have happened to the number of participating bidders and their bids in the absence of joint bidding. With data from the Austrian construction sector, we estimate models of first-price sealed-bid auctions with endogenous entry and run counterfactual simulations. Our results show that forbidding bidding groups or confining them to small firms would decrease the number of participating bidders only slightly, but would increase winning bids by about two percent. To the detriment of the auctioneer, other, less efficient, firms would enter the bidding process and replace the bidding groups.

JEL Classifications: D44, L10, L13

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# 1 Introduction

Public procurement of government contracts accounts for a large part of GDP in many countries. Firms participating in these auctions usually submit a single bid, but under certain conditions firms are also allowed to form bidding groups and submit joint or consortium bids. There is evidence for joint bids, for example, in the US (Hendricks and Porter, 1992), Italy (Branzoli and Decarolis (2015), Rondi et al. (2017)) or Japan (Iimi, 2004).[1] Recurring questions in public procurement concern the competitive effects of joint bidding, whether joint bidding should be allowed, or whether only specific types of joint bidding should be allowed (e.g. involving firms with a small market share).[2]

Joint bidding is a situation where two or more firms bid together for a contract, the potential customer can observe that firms submitted a joint bid and all participants enter the contract with the customer if the bidding group wins.[3] The question that arises is whether bidding groups reduce competition in those auctions where they participate, as fewer bidders participate. Or, whether they have a pro-competitive effect, because firms that participate in a bidding group would have otherwise not submitted a stand-alone bid (e.g. due to capacity constraints) or because the formation of the bidding group allowed to increase efficiency (e.g. due to combining complementarities or specific assets). Another aspect concerns whether the competitive effects depend on the type of bidding group, i.e., whether small or large firms are members of the bidding group.

We analyze these questions using a structural auction model and data from the Austrian construction sector.[4] Based on estimated bidding distributions and bidders' entry behavior, we run counterfactual simulations to assess the competitive effects of joint bidding. In particular, we ask whether in the absence of a joint bid, there would be more or fewer independent bids, and whether these bids would yield a different auction outcome. We investigate the effect of prohibiting bidding groups on the number of participating bidders and the winning bid, and analyze the effects of

[1] Hendricks and Porter (1992) reports 24% joint bids in a sample of auctions for oil lease tracts in the years 1954-1969. Iimi (2004) reports 27% of joint bids in a sample of procurement and construction auctions for governmental agencies and official development assistance in Japan in the years 1999-2002. In the sample of this paper, i.e., Austrian construction sector in the years 2006-2009, we observe 30% winning joint bids in terms of project value.

[2] The questions are also of interest to competition authorities who have introduced guidelines covering joint bidding as well. See, for example, the US 2000 Antitrust Guidelines for Collaboration Among Competitors and the 2011 European Commission Guidelines on Horizontal Cooperation Agreements.

[3] In the remainder, we will use the terms "joint bidding", "bidding groups", or "consortium bids" as well as the terms "single bid" or "stand-alone bid" interchangeably.

[4] In our setting, the treatment of bidding groups concerns public procurement, but the results are likely also of interest for private auctioneers when setting rules for bidding groups.

restricting bidding groups to small firms or allowing bidding groups only when a small firm participates. With our analysis we relate to the literature on the effects of joint bidding (Hendricks and Porter (1992), Branzoli and Decarolis (2015), Rondi et al. (2017), Iimi (2004), Moody Jr and Kruvant (1988) and Estache and Iimi (2009)), and on small firm policies and bid preference programs (Marion (2007), Krasnokutskaya and Seim (2011), Athey et al. (2013)). While we still restrict the formation of bidding groups to be exogenous, we allow firms to form bidding groups from all possible firm combinations. This enriches our entry model by giving the firms the choice between entering an auction and submitting a single or a joint bid. We thus predict entry probabilities with a higher precision than we would, if we let firms decide only whether to enter an auction or not.

Our data set covers more than 80% of all auctions in the Austrian construction sector which had to be conducted according to the Austrian Public Procurement Law during the period 2006-2009. It includes own and competitors' bids as well as bidder and auction characteristics in both building and heavy construction. With these data, we are able to calculate two measures of firm-time specific costs: the backlog of projects and transportation costs, i.e., the travel distance of a firm to the construction site. To obtain firm characteristics such as the number of employees, sales and assets of companies in Austria, we match the bidding data with Bureau van Dijk's Amadeus database. The final sample for the estimations consists of 2,054 auctions and nearly 15,000 bids by 968 firms. About 5% percent of these bids are joint bids, however, this number masks the economic importance of joint bidding: joint bids win in 10% of auctions and winning joint bids account for 30% of project value. With these data we estimate a static bidding model of first-price actions that also accounts for endogenous entry (following Li and Zheng (2009), Krasnokutskaya and Seim (2011), Athey et al. (2011)) and unobserved heterogeneity (following Krasnokutskaya (2011)).

For our counterfactual analysis, we model the entry behavior of firms to assess whether the members of the bidding groups would have submitted stand alone bids. We assume that bidders incur fixed entry costs. Using the estimated distribution of bidders' costs, we estimate bidders' entry costs based on observed entry behavior following Li and Zheng (2009), Krasnokutskaya and Seim (2011) and Athey et al. (2011), augmenting their approach to allow firms to form bidding groups as well. We model this decision process with a conditional logit choice model. This allows every bidder to choose whether to enter with a single bid or within a bidding group or to not enter at all. We assume that each firm can form a bidding group with any other firm that is a potential bidder in the auction. The entry probabilities can then be expressed as functions of auction and firm characteristics as well as differences in bidder characteristics due to the formation of a bidding group.[5] Our model predicts actual outcomes well. For example, the mean observed bid is 2.310 million euro while the mean predicted bid is about the same with 2.302 million euro. Or, the observed average number of bids as well as the predicted number of bids is 7.3.

We then run two types of counterfactuals. First, we investigate the effect of prohibiting bidding groups on winning bids and the number of bidders. Second, we ask if small firms would benefit from a policy that allows only small firms to form a bidding group. In addition, we analyze these two scenarios once by fixing the number of bidders to the observed level, and once by allowing for endogenous entry. Dissolving a bidding group means replacing the group values of distance, size and backlog for the individual values of each member of the bidding group. When endogenous entry is allowed, we let potential bidders enter based on profit considerations. After dissolving bidding groups, market structure also changes through a change in the number of bidders, size of other firms, distance of other firms and backlog of other firms. There is also a change in cost as (own) size, distance and backlog are changing.

Our counterfactuals (forbidding bidding groups altogether; allowing only small firms to form bidding groups; and allowing small/large but not large/large combinations) yield the following results. Although participation would decrease only slightly (on average, by 0.2 to 0.5 bids per auction depending on the scenario), forbidding bidding groups altogether would increase winning bids by about two percent. This would damage the auctioneer (i.e. the state and the taxpayer) and indicates that less efficient bidders enter the bidding process once bidding groups are not allowed to bid. Allowing only small firms to form bidding groups and allowing only small/large combinations, do not alter this result. The reason is that when forbidding large/large combinations then fewer large firms take part in public procurement auctions and other firms — less efficient firms — enter the bidding process. For many public procurement projects — large and complex projects —, it would be most efficient if two large firms combine forces.

In the next section, we discuss the related theoretical and empirical literature. Section 3

[5] Potential changes in bidder characteristics due to the formation of a specific, potentially hypothetical bidding group are, for example, changes in bidder size or the change in the distance to the procurement site.

provides the industry background of the Austrian construction sector, explains the rules of the procurement process, the legal situation, and describes the auctions and bidding groups in our sample covering the period 2006 to 2009. We also have a descriptive look at the effects of bidding groups on winning bids and the number of bidders. Section 5 sets up our first-price sealed bid auction model accounting also for endogenous entry. Section 6 presents the estimation results and Section 7 the counterfactual analysis. Section 8 concludes.

## 2 Related literature

In the following subsections we describe the related literature. We discuss the theoretical literature in Subsection 2.1 and the empirical evidence in Subsection 2.2.

### 2.1 Theoretical literature

The theoretical literature on the effects of joint bidding can be distinguished between first and second price auctions, and between common value and private value auctions. Since our case is a first price private value auction, we refer to results on common value and/or second price auctions only in footnotes. Froeb and Shor (2005) is a concise survey of the auction literature on the effects of collusion and mergers also holding arguments for the case of joint bidding. Generally speaking, coalitional bidding potentially influences auction outcomes through changing the number of participating bidders and through affecting bidders' underlying private values or signals.[6]

The antitrust implications are different for private and common value auctions. Mergers or bid consortia in private value auctions follow the intuition of traditional markets: They are likely to be anticompetitive in the absence of offsetting efficiency gains.[7] In a private value auction, competition results in efficient trade because buyers bid whenever their value exceeds the reserve

[6]Bouckaert and Van Moer (2016) investigates joint bidding when firms, after competing in the main market, can sign subcontracts with each other. While they analyze how joint bidding changes the terms of trade on the horizontal subcontracting market, our focus is on the effect of joint bidding on prices and participation in the main market.

[7]For common value auctions — because of "winner's curse" arguments — the very existence of anticompetitive effects is not assured. For example, DeBrock and Smith (1983) or Hendricks et al. (2008) show that collusion does more than simply transfer rents from the seller to the buyers, it also gives buyers a chance to pool their information prior to trade and make an efficient investment decision. Thus, the anticompetitive effects of a reduced number of bidders tend to be offset by the fact that better informed participants bid more aggressively. However, full efficiency may not be compatible with information revelation. Buyers with high signals may be better off if no one colludes, leading to inefficient trade.

price, and their value is independent of their rivals' signals. Hence the asset is sold if and only if at least one agent's value exceeds the reserve price. One way to model the effect of a merger or a joint bid is to assume that the private value of the bidder is the maximum of its coalition member values. This characterization has been used by antitrust enforcement agencies to model unilateral effects of mergers and in the existing literature on mergers/joint bidding in auction markets (see e.g. Ashenfelter et al. (2015), Li and Zhang (2015), Cantillon (2008), Waehrer and Perry (2003), Brannman and Froeb (2000), Dalkir et al. (2000), or Waehrer (1999)).

In first-price auctions, the relationship between observed bids and underlying values is complex because bidders do not have an incentive to bid their true values.[8] Instead, they balance the benefits of a lower bid (a higher probability of winning) against its costs (lower profit if they win). Observed bids are higher than values, and the amount of shading of bids above values depends upon each bidder's beliefs of the likely bids of other participants.[9]

Consortium bids differ from mergers since they are formed temporarily, i.e. just for the project at hand or possibly repeatedly for more than one project over time, while mergers are permanent arrangements. Thus, to judge the effects of joint bids one has to assess whether the joint bid leads to a lower number of total bids, to an equal number of bids or whether the joint bid has an even increased probability of taking part in the auction compared to the sum of pre-bid individual likelihoods. Moreover, one has to assess changed efficiency/behavior of joint bids.

## 2.2 Empirical evidence

This section reviews the empirical literature on the effects of joint bidding on the likelihood of entry and the final outcome of the bidding process. It should be noted that the studies are reduced form estimations and there are no studies that look at structural auction models to assess the empirical effects of joint bidding. In closing this section, however, we will review several structural estimations on auctions that have — as we have — implications for "small firm policies".

[8]Since bidders bid their true values in a second-price auction, it is relatively easy to quantify the effects of a merger or joint bid: A merger/joint bid pushes down the price to the third-highest bid when the bidders would have finished first and second. For all other bidder pairs, the merger/consortium bid has no effect.

[9]Froeb and Shor (2005), therefore, state that "mergers in first-price auctions affect prices in subtle and complex ways". By analogy, the same can be said for joint bids.

We again concentrate on empirical studies on private value auctions.[10] Iimi (2004) uses auction data on Japanese official development assistance (ODA) procurement, which is a first price sealed bid auction with private value characteristics. Joint bids are very important in Japan: 27% of bids are joint bids. While consortium bids are more likely on difficult and large projects (consistent with Hendricks and Porter (1992)), the author finds that joint bidding has only pro-competitive effects if local bidders are involved. Thus, the effects of joint bidding depend on the type of bidders. Consistent with these results, Estache and Iimi (2009) show for cross country ODA auctions on road projects that joint bidding involving local enterprises is especially pro-competitive, while this may not be the case with foreign firms. Moreover, there is evidence of endogeneity, since the occurrence of joint bidding is related to auction and firm specific variables such as the size of the project, to backlogs as well as to country specific variables such as regulatory quality, rule of law and anticompetitive policies.

More recently, Branzoli and Decarolis (2015) and Rondi et al. (2017) use Italian procurement data to — while also analyzing the effects of subcontracting — explicitly analyze the effects of "temporary joint ventures" (TJVs), legal forms very similar to bidding groups in Austria.[11] Both papers find beneficial effects of joint bidding. Branzoli and Decarolis (2015) show that when buyers choose a more competitive auction format (a move from average bid auctions (ABA), where contracts are allocated like in a random lottery and at high prices, to first price auctions (FPA)) — besides reducing the winning bids — TJVs display much larger participation rates and more than double their winning probabilities. Rondi et al. (2017) find that TJVs improve market performance relative to ex post mandatory subcontracting.

Thus, the extant literature on joint bidding in private value auctions predominantly finds positive (welfare improving) results, however only if firm (e.g. capital constraints, complementarities) or information constraints (e.g. on local information) are mitigated. The above studies highlight also the selection problem, i.e. joint bidding endogenously forms as a response to the characteristics of the project/auction (e.g. larger, more riskier projects increase the probability of a joint bid) and to firm specific variables such as the backlog. There does not exist a structural analysis of joint

[10] See Moody Jr and Kruvant (1988) and Hendricks and Porter (1992) for (positive) effects of joint bidding in a common value set up.

[11] One difference is that in Austria firms forming a bidding group are usually jointly and severally liable, while in Italy at least one firm has to be declared the leader in a TJV, which is responsible for the execution of the entire contract, whereas the other members of the TJV are responsible exclusively in proportion to their share of the TJV.

bidding accounting for endogenous entry so far in the literature, however.

Nevertheless, there are several papers estimating structural auction models that have implications for "small firm policies". Athey et al. (2011) estimate a private value auction model with endogenous participation. Using data from the U.S. Forest Service timber auctions, they find that sealed bid auctions attract more small bidders, shift the allocation towards these bidders, and can also generate higher revenue than an open format. The reason is that in a sealed-bid auction, stronger bidders (i.e. larger firms) have a greater incentive to shade their bids below their true valuations, so weaker bidders (i.e. smaller firms) may win the auction despite their efficiency disadvantage. Accounting for endogenous entry is important in that respect. Below we also account for endogenous entry processes.

Somewhat in line with Athey et al. (2011), Nakabayashi (2013) finds positive net effects of small business set-asides in Japan for the government. In Japanese public construction projects approximately half of the procurement budget is set aside for small and medium enterprises (SMEs). Applying an asymmetric first-price auction model with affiliated private values, the author shows that around 40 percent of SMEs would not bid in procurement auctions if set-asides were removed. The resulting lack of competition would increase government procurement costs more than it would offset the small firm production cost inefficiencies. This finding is somewhat in contrast to our finding of not finding positive effects of a policy that only allows bidding groups if a small firm is part of it.

In contrast to Nakabayashi (2013) and in line with our findings, Krasnokutskaya and Seim (2011) and Marion (2007) find negative net effects of bid preferences in procurement auctions to the auctioneer in California auctions for road construction contracts. Small businesses receive a 5-percent bid preference in auctions for projects using only state funds but no preferential treatment on projects using federal aid. Marion (2007) finds that procurement costs are 3.8 percent higher in auctions using preferences due to reduced participation by lower cost large firms. Similarly, Krasnokutskaya and Seim (2011) find that while the cost of procurement is within 1.5 percent of the cost in the absence of discrimination, the program does not achieve its goal of allocating 25 percent of procurement dollars to small firms. Again, the program induces substantial changes in small and large firms' participation and probabilities of winning. Consistently, we find that restricting joint bidding to small firms would induce entry of small, inefficient bidders as well as fewer bids of large, efficient firms. Below we show that such a policy would lead to an increase of procurement costs of around 2%.

# 3 Industry background

This section provides information on the organization of Austrian procurement auctions and the legal situation in the EU, also making a comparison to the US.

## 3.1 Organization of procurement auctions

In Austria, federal and regional governments or other public institutions who want to procure contracts are subject to the Public Procurement Law (PPL, "Bundesvergabegesetz").[12] This law specifies the legislative framework for public procurement, which includes services like cleaning, facilities like computing or furniture, and construction such as rails, roads, schools and other public buildings, etc. Our data are exclusively on procurement from the construction sector. The main purpose of the PPL is to stimulate competition and safeguard equal treatment of all potential bidders.

There are some restrictions on bidders in place. For example, bidders have to prove their commercial and professional abilities as well as general, non-discriminatory standards of qualification[13] and have to provide a 5% bid bond. The public authority must choose between an "open procedure" or a "restricted procedure with publication of a contract notice". Nearly 90% of the projects are conducted according to an "open procedure", in which auctions are open to all firms, while in other auctions, the seller invites a restricted sample of firms only.

In principle, there are no lower limits for the applicability of the PPL. For small contracts, however, a procuring institution has the possibility to nominate a firm directly, without conducting an auction.[14] Our data do also contain projects below these limits, which are therefore voluntarily

[12] Private companies (as sellers) have to follow these rules only if (i) they are active in a "sectorial activity" (provision of water, mail services, energy, or traffic), or (ii) their activity is regulated (e.g. entry regulations).

[13] For example, a procuring institution may demand supporting documents about the availability of certain necessary machinery or qualified personnel.

[14] The limit for direct nomination vary in the sample period: 20,000 euros for 01/2006, 40,000 euros for 02/2006-4/2009, 100,000 euros for 05/2009-12/2009.

procured via auctions. There are upper limits that enforce the EU-wide announcement for larger projects (around 5 million euros during the period of our sample).

After the project announcement in the corresponding official publication medium, the procuring institution makes the documents available to the bidders. Once the submission period has finished, the seller opens the sealed offers and informs the bidders. The bid with the lowest price wins the contract. Thus, all auctions are conducted as first-price sealed bid auctions.

In general, there exists no reserve price and the procuring institution can only withdraw the auction, if it can prove in court that the bid of the winner is "contra bonos mores" ("against good morals"). The burden of proof to show that the winning bid is far higher than its own cost estimate is with the auctioneer.

### 3.2 Legal situation

If a bidding group affects trade between member states it falls under EU legislation, if not, it falls under national (Austrian) competition law. The overwhelming majority of bidding groups do not affect trade between member states. The legal rules are similar, however.[15]

As the European Commission indicates in its guidelines (European Commission, 2011), horizontal cooperation agreements can lead to substantial economic benefits, in particular if they combine complementary activities, skills, or assets; horizontal cooperation can be a means to share risk, save costs, increase investments, pool know-how, enhance product quality and variety, and launch innovation faster. From a legal perspective a consortium bid would not violate antitrust law if consortium members would not be able to undertake the project individually or with a more limited number of parties.[16]

Joint bids fall under Art. 101(1) TFEU, if they restrict competition.[17] This is the case if the

[15] Thomas (2015) summarizes the legal situation of joint bidding under EU legislation.

[16] Thomas (2015) states that "the real question is rather whether, in the absence of the joint bid, there could in fact have been two or more independent bids."

[17] Joint bidding differs from subcontracting where one firm bids as a sole contractor and passes on some of the work to another firm. With subcontracting only the winning firm directly enters the contract with the customer, but not the subcontracting firm. In public procurement, there are special rules concerning subcontracting. For example, in public procurement in Austria all subcontractors have to be named at the auction stage, and subcontracting of the whole contract is not allowed. If additional subcontractors enter and/or if subcontractors leave the contract after the auction, this must be made known to the customer. To prevent circumventing the rules on joint bidding, subcontracting is not allowed if the subcontracting firm could have fulfilled the contract on a stand alone basis. See

motivation to form the bidding group was a restriction of competition in the first place, e.g. by price fixing. Besides that, legality of a bidding group is a question of the competitive effect it ultimately has. According to the European Commission's Guidelines on horizontal cooperation agreements, production agreements are permitted if they result in efficiency gains and the concrete agreement is the only way to achieve these efficiencies. Also, the efficiency gains must not benefit the producers only, but be passed-on to the customers, too. Finally, competition must not be eliminated entirely.

Bidding groups do not fall under Art. 101(1) TFEU, if they are not too large, because a "de minimis rule" applies to firms that are small relative to the market size. A de minimis rule for "agreements of minor importance" is in effect in EU law only if the effect, but not the purpose ("by object"), was a restriction of competition. This de minimis rule holds when the market share of the bidding group is below 10 percent. Until the beginning of March 2013, for bidding groups covered by national (Austrian) legislation, this de minimis rule applied to joint market shares of below 5 percent (or, below 25 percent in "submarkets") even to bidding groups with the purpose of price fixing.[18]

Legal rules on joint bidding are very similar in the USA. The standards the FTC or the Department of Justice use to determine whether a joint bid violates antitrust laws are set out in the 2000 Antitrust Guidelines for Collaboration Among Competitors. Similarly to EU law, the ultimate question is whether "cognizable efficiencies" due to a joint bidding arrangement are sufficient to offset any anticompetitive harms. In the USA there is a "safety zone" for collaborations that are not per se illegal[19] and that do not account for more than 20% of the market. Thus, the "US de minimis rule" is more lenient to jointly bidding firms than the EU rule (20% versus 10% market share).

Summarizing, in both large jurisdictions, the USA and the EU, joint bidding is legal if efficiencies due to the collaboration outweigh any market power effects, with the exception of "hard core" restrictions, which are illegal per se. Both jurisdictions have special rules in favor of small firms

also the literature on subcontracting, e.g. Moretti and Valbonesi (2015), Miller (2014), Marechal and Morand (2003), and Spiegel (1993).

[18]The Austrian rule was replaced by a 10 percent threshold and exclusion of the exception for hardcore restrictions (like price fixing), in harmonization with the de minimis rule in EU law, in 2013. As stated above, EU-law was applicable also before 2013 when there was "appreciable effect on trade between member states".

[19]A joint bid is per se illegal if each member of the group could have performed the contract alone and there is no integration of operations such that there are no efficiencies. See e.g. the case FTC v. B&J School Bus Services, Inc., 116 F.T.C. 308 (1993).

provided the joint bid is not a restriction of competition by object or per se illegal. In Austria, until 2013, there was an exception to this rule, since the de minimis rule even applied to bidding groups with the purpose of price fixing provided that joint market shares were below 5 percent (or, below 25 percent in "submarkets"). In our context, the implied difference in the rules for smaller bidders is important for two reasons: (1) market power effects could be stronger for bidding groups *relative to their efficiency effects* among firms with smaller market shares, because they are not subject to the strict rules on efficiency gains; (2) a de minimis rule or a safety zone can be interpreted in this case as a small bidders' subsidy.

# 4 Data and descriptive evidence

This section provides information on the data we use for our empirical analysis. We provide summary statistics and also describe the characteristics of the bidding groups.[20] Finally, we provide descriptive regression analysis that assesses the determinants of winning bids and the number of bidders.

## 4.1 Data and bidding groups

Data on procurement auctions have been provided by one Austrian industrial construction company. The data include own and competitors' bids, bidders' and auction characteristics, and cover auctions in both building and heavy construction during the period 2006-2009 where this company took part either as the parent company itself or through a subsidiary. According to the company, the data cover more than 80% of all auctions in the construction sector which must be conducted according to the Austrian Public Procurement Law.[21,22]

Additional data are obtained from matching the bidding firms to Bureau van Dijk's Amadeus database, which contains firm characteristics such as number of employees, sales and assets of companies in Austria. Matches are unique by company names and postal codes. We measure

[20] Further information on the industry and data is available in Gugler et al. (2015a) and Gugler et al. (2015b).

[21] The construction sector accounts for 7% of Austria's GDP on average between 2006 and 2009. Within our sample period, the data reflect on average 14% of Austria's total construction sector.

[22] As our sample only contains the procurement auctions in which the data provider participated as a bidder, our empirical analysis may suffer from a sample selection bias. Our data provider is a large firm. Thus, it is more likely that we do not have data from smaller procurement auctions than from larger procurement auctions.

transportation costs by the distance of a firm to a construction site.[23] Backlog of a firm at a point in time is calculated as in Jofre-Bonet and Pesendorfer (2003). Every project is added to the backlog when a firm wins it. Projects are assumed to be worked off linearly over their construction period, which releases capacity. Every firm's backlog obtained is standardized by subtracting its mean and dividing by its standard deviation. Table 1 contains an overview of the variable descriptions.

Table 1: Variable descriptions

| Variable | Description |
|---|---|
| *Actual bidders* | Number of bidders in the auction. |
| *Backlog* | Backlog variable, standardized by firm mean and standard deviation. |
| *New orders* | Gross inflow of new contracts, countrywide, per month in construction sector (mill. 2006 euro). |
| *Engineer estimate* | Engineer cost estimate for the construction project. |
| *Employees* | Number of employees of a bidder. |
| *Distance* | Travel distance in kilometers from a bidder's location to the project site. |
| *Heavy construction* | Dummy for auctions in heavy construction sector. |
| *General contractor* | Dummy for bidders serving as "general contractors". |
| *Open procedure* | Dummy for auctions following the "open procedure". |
| *Potential bidders* | Number of potential bidders. |

### 4.2 Sample and summary statistics

Table 2 describes our sample of auctions and firms. For the econometric model, we lose observations, mainly when there is no engineer estimate in our data. We do not use observations when firms have gone bankrupt or have been dissolved, and when we cannot match firms to the BvD database. The final sample for the estimations consists of 2,054 auctions and 968 firms. The firms matched to external information account for 94% of our bids. The population of Austrian construction firms, as reported by the Austrian Central Bureau of Statistics, consists of 4,796 firms on average for 2006-2009 (building: 3,958, heavy: 838). Of these 4,796 construction firms, 1655 firms submitted bids in the procurement auctions. This is about 35%.

In Table 3, we show summary statistics of our sample. On average 7.6 firms take part in Austrian procurement auctions in the construction sector. While the number of Austrian construction firms

[23] Based on the construction sites' and bidders' postal codes, we used Microsoft's Bing Maps to calculate the driving distances for all bidders to the project sites corresponding to the auctions. For firms with multiple plants, we use the distance between the headquarter and the construction site. Plant locations are not available; different locations of a firm, though, are often operated as subsidiaries and distances then can be calculated.

Table 2: Description of the sample

| Sample | Observations |
|---|---|
| Auctions | 3,974 |
| *minus* engineer estimate n.a. | 2,249 |
| *minus* outliers | 2,054 |
| Firms | 1,655 |
| *minus* bankrupt, dissolved | 1,556 |
| *minus* non-matched BvD data | 1,342 |
| *minus* non-matched BvD variables | 968 |

Notes: The top-panel shows the number of auctions in the sample and the reason why it is reduced in each line, together with the corresponding new number of observations. Below that, the second panel reports the number of firms that submitted bids. The 968 firms matched account for 94.0% of bids in the econometric model of 2,054 auctions.

of almost 5,000 firms on average also suggests a highly competitive market environment, there are a few large construction companies, too,[24] and there is differentiation both in the product and the spatial dimension. The firms in our sample, with a few exceptions, are mostly medium sized companies with around 50 employees.

Table 3: Summary statistics

| | | Participation | | Potential bidders | |
|---|---|---|---|---|---|
| | | mean | s.d. | mean | s.d. |
| Auctions | Number of auctions | 2,054 | | | |
| | Winning bid (mill.) | 2.049 | 4.281 | | |
| | Engineer estimate (mill.) | 2.190 | 4.117 | | |
| | New orders (mill.) | 1,720.8 | 180.91 | | |
| | Heavy construction | 0.343 | 0.475 | | |
| | General contractor | 0.085 | 0.279 | | |
| | Open procedure | 0.832 | 0.374 | | |
| | Actual/Potential bidders | 7.63 | 3.171 | 29.57 | 11.52 |
| Firms | Number of firms | 968 | | 1,414 | |
| | Employees (mean) | 175.70 | 1,779.8 | 131.93 | 1,477.6 |
| | Employees (median) | 41.13 | | 28.24 | |
| Bidders | Number of bids/observations | 14,803 | | 48,036 | |
| | Bid (mill.) | 2.029 | 3.910 | | |
| | Backlog | 0.085 | 0.830 | 0.081 | 0.883 |
| | Distance (km) | 130.38 | 121.69 | 119.79 | 115.99 |

Notes: Top panel: Means and standard deviations for auction characteristics. Middle panel: comparison of participating (submitting a bid) and all potential bidders. Bottom panel: bids and characteristics from participating bidders and characteristics of the subset of potential bidders that do not submit a bid. Monetary values in 2006 euro.

[24]The largest four firms have approximately 40% market share within our sample of procurement auctions.

The entry model requires a definition of potential bidders. One might consider all firms that do not participate in a specific auction as potential bidders. This yields too many firms. We thus restrict potential bidders. For each calendar year, we look at three participation criteria, sector of activity, size of auction, and distance to project site. The first criterion is in which sector (heavy construction/building) firms participate. We define bidders that bid only in heavy construction in that calendar year to be potential bidders in heavy construction auctions. The same is true for building construction. Only if firms bid in both types of auctions, they are potential bidders in both types of auctions. Second, we ask whether firms participate in large or small auctions measured by the engineer estimate. We restrict firms to be potential bidders in auctions where the auction value (engineer estimate) is not more than three times the maximum auction value in earlier auctions in that calendar year where the bidder participated. Finally, we calculate the maximum distance between a firm's headquarter and the procurement site of an auction a firm participated. We request that firms are only potential bidders within their maximum distance in that calendar year to qualify as a potential bidder. This gives on average about 30 potential bidders per auction. We observe that they are smaller than actual bidders.

In Table 4, we show summary statistics on bidding groups. In around 26% (533/2,054) of auctions at least one bidding group participates. While only around 5% (757/14,803) of bids are by bidding groups, around 10% win. Since bidding groups participate and win in much larger auctions, winning bidding groups account for around 30% of total procurement value. Bidding groups are larger in size and farther away from procurement sites. Their winning bids are larger than of single bidders, indicating that bidding groups participate in auctions for larger projects, which are more likely in heavy construction. Bidding group auctions request less likely a general contractor and are run more likely in an open procedure, i.e., not only invited firms may participate.

To find out more about the characteristics of bidding groups and their formation, we additionally have a look at characteristics of bidding groups in Table 5. Bidding groups of up to five members are observed in our data, with an average number of members of 2.17 firms. Some bidding groups are formed on a regular basis participating up to 30 times in the sample, while about two thirds of the bidding groups only form once. Up to five bidding groups participate in specific auctions, with an average number of 1.5 bidding groups per auction where at least one group participated.

Table 4: Comparison of single bidders and bidding groups

| | | W/o bidding groups mean | s.d. | Bidding groups mean | s.d. |
|---|---|---|---|---|---|
| Auctions | Number of auctions | 1,521 | | 533 | |
| | Winning bid (mill.) | 1.244 | 2.847 | 4.345 | 6.360 |
| | Engineer estimate (mill.) | 1.328 | 2.621 | 4.651 | 6.132 |
| | New orders (mill.) | 1,722.5 | 181.3 | 1,715.9 | 180.0 |
| | Heavy construction | 0.249 | 0.433 | 0.612 | 0.488 |
| | General contractor | 0.097 | 0.296 | 0.053 | 0.223 |
| | Open procedure | 0.790 | 0.408 | 0.951 | 0.216 |
| | Actual bidders | 7.75 | 3.24 | 7.30 | 2.96 |
| | Potential bidders | 29.75 | 11.91 | 29.03 | 10.31 |
| Firms | Number of firms/groups | 934 | | 345 | |
| | Employees | 173.09 | 1,810.8 | 3,379.7 | 3,485.2 |
| | Employees (median) | 40 | | 2,221.8 | |
| Bids | Number of bids | 14,046 | | 757 | |
| | Bid (mill.) | 1.795 | 3.382 | 6.369 | 8.187 |
| | Backlog | 0.084 | 0.838 | 0.114 | 0.664 |
| | Distance | 129.36 | 122.92 | 149.43 | 91.99 |

Notes: Means and standard deviation for auctions without bidding groups and with bidding groups. Top panel: comparison of auction characteristics between the two groups of auctions. Middle panel: comparison of single firms versus unique group combinations submitting bids. Bottom panel: comparison of bids and characteristics of the single firms and groups, based on bids submitted. Monetary values in 2006 Euro.

The mean relative size is 0.303. We calculate the relative size by dividing the size of the smallest member of the bidding group by the size of its largest member. Thus, the largest firm in a bidding group is on average around three times as large as the smallest firm.

Table 5: Characteristics of bidding groups

| Number of bidding group members | 2 | 3 | 4 | 5 | Total |
|---|---|---|---|---|---|
| Number of bids from bidding groups | 639 | 110 | 5 | 3 | 757 |

| Participated | 1 | 2 | 3 | 4 | 5 | 7 | 8 | 9 | 10 | 15 | 16 | 17,18,19,24,30 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| # of groups | 233 | 42 | 31 | 12 | 6 | 5 | 2 | 2 | 3 | 2 | 2 | 1 each | 345 |

| Number of bids from bidding groups per auction | 1 | 2 | 3 | 4 | 5 | Total |
|---|---|---|---|---|---|---|
| # of observations | 329 | 111 | 44 | 16 | 2 | 757 |

| | mean | s.d. | median | min | max |
|---|---|---|---|---|---|
| Relative size | 0.303 | 0.251 | 0.251 | 0.001 | 0.977 |

Notes: Characteristics of bidding groups are the number of bids coming from bidding groups per size of bidding group, how often bidding groups participated, number of bids from bidding groups per auctions and relative size calculated by dividing the size of the smallest member of the bidding group by the size of its largest member.

### 4.3 Effects of bidding groups

The first step of our analysis are descriptive regressions that assess determinants of winning bids and the number of bidders. As Table 5 has shown some bidding groups participate on a more regular basis than others and some bidding groups are more heterogenous than others. Besides dummy variables for bidding groups, we distinguish bidding groups that are bidding only once or twice ("group bidding once or twice") as well as bidding groups that include only small firms ("small group") and bidding groups with at least two large firms ("large group"). We define small firms as having below median number of employees and large firms as having above median number of employees.

Table 6 shows the results for winning bids. In Column (1), we depict the results for the full sample; in the other columns we reduce the sample to the auctions in which bidding groups have participated. In column 1 with the full sample, we find that winning bids are higher for bidding groups but lower for auctions where bidding groups participated. Winning bids are higher by about 400 thousand Euro when a bidding group wins, which amounts to about 20% of the mean winning bid. However, the results using the full sample also show that bids in auctions where bidding groups participate are lower by about 360 thousand Euro indicating that once controlling for auctions characteristics like the engineer estimate or the number of firms winning bids in these auctions are on average lower by about 18%. This implies that bidding groups win in larger auctions, and that their participation appears to have a dampening effect on all winning bids. The other variables have the expected signs in all specifications. For example, the larger the number of firms that participate in the auction, the lower is the winning bid, and the higher the engineer estimate, the higher the winning bid. There are no substantial differences in winning bids across types of bidding groups with the possible exception winning bidding groups involving only small firms which appear to be different from bidding groups involving only large firms (lower winning bid significant at the 10% level). They display winning bids similar to auctions with no bidding groups.

Table 7 shows the results for regressions of the number of bidders on the same indicators as in Table 6. We find that if bidding groups win, the number of bidders is lower (by 1.7), while the number of bidders is not lower in auctions where they just participate. This indicates that bidding

Table 6: Determinants of winning bids

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| Constant | -28.49 | -150.14 | -169.97 | -132.96 |
| | (216.37) | (793.55) | (796.15) | (793.82) |
| Bidding group wins | 395.64*** | 397.69*** | 376.08** | 593.66*** |
| | (82.02) | (143.14) | (155.54) | (212.85) |
| Bidding group participates | -365.02*** | | | |
| | (62.17) | | | |
| Bidding group wins × group bidding once or twice | | | 82.45 | |
| | | | (231.11) | |
| Bidding group wins × small group | | | | -652.84* |
| | | | | (384.29) |
| Bidding group wins × large group | | | | -204.70 |
| | | | | (230.26) |
| Number of firms | -13.35* | -54.96** | -55.05** | -52.15** |
| | (6.85) | (24.98) | (25.01) | (25.17) |
| Engineer estimate in thousand Euro | 1.01*** | 0.99*** | 0.99*** | 0.99*** |
| | (0.01) | (0.01) | (0.01) | (0.01) |
| Auction characteristics | Yes | Yes | Yes | Yes |
| Adjusted R-squared | 0.953 | 0.941 | 0.941 | 0.941 |
| Number of observations | 2,054 | 533 | 533 | 533 |

Notes: Dependent variable is the winning bid. Auction characteristics are a dummy variable for heavy construction, a dummy variable for general contractor, a dummy variable for open procedure and the value of new orders. Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

groups win in auctions with fewer bidders, which may be a sign that they win in more complex projects, where fewer bidders are competitive. Consistently, we further find that the number of bidders is negatively correlated with the engineer estimate. Again, auctions where winning bidding groups involve only small firms appear to be different from the "large group", and resemble auctions with no bidding groups. Our results underline possible endogeneity as well as selection problems.

To summarize, the descriptive regression results imply that there are differences between bidding groups and stand alone bidders. Bidding groups submit higher bids and participate in auctions with fewer bidders. These results are indicative that the structural bidding model should account for endogenous entry and the decision to participate as a bidding group.

## 5 Structural model

The basis of our counterfactual analysis is a stylized structural model that takes into account that participation in auctions is costly and the bidder with the lowest bid wins the contract. We thus

Table 7: Determinants of number of bidders

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| Constant | 10.879*** | 12.215*** | 12.192*** | 11.826*** |
| | (0.656) | (1.278) | (1.284) | (1.277) |
| Bidding group wins | -1.690*** | -1.559*** | -1.583*** | -1.356*** |
| | (0.262) | (0.240) | (0.263) | (0.365) |
| Bidding group participates | 0.238 | | | |
| | (0.201) | | | |
| Bidding group wins × group bidding once or twice | | | 0.092 | |
| | | | (0.403) | |
| Bidding group wins × small group | | | | 1.229* |
| | | | | (0.665) |
| Bidding group wins × large group | | | | -0.548 |
| | | | | (0.399) |
| Engineer estimate in million Euro | -0.064*** | -0.072*** | -0.072*** | -0.069*** |
| | (0.018) | (0.020) | (0.020) | (0.019) |
| Auction characteristics | Yes | Yes | Yes | Yes |
| Adjusted R-squared | 0.117 | 0.166 | 0.165 | 0.177 |
| Number of observations | 2,054 | 533 | 533 | 533 |

Notes: Dependent variable is the number of bidders. Auction characteristics are a dummy variable for heavy construction, a dummy variable for general contractor, a dummy variable for open procedure and the value of new orders. Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

model the bidding process in two stages. In the first stage, firms decide whether to enter an auction as a single bidder, within a bidding group or to stay out of the bidding process. A set of potential bidders makes this decision and we define this set of potential bidders in more detail below. We assume that the formation of bidding groups is exogenous.[25] In the second stage, each bidder, who can be either a single bidder or a bidding group, gets a draw of its cost to run the contract and submits a bid. We model the cost draw of a bidding group as a function of the underlying cost of its members.

## 5.1 Bidding behavior

In our model, the bidding process follows a standard first-price sealed bid auction in which the bidder with the lowest bid wins.[26] We assume that each contract is an auction independent from

[25] Here, we follow the literature that studies bidding rings and where the formation of bidding rings is taken as exogenous. For a survey on bidding rings see, for example, Asker et al. (2010). For endogenous formation of bidding rings in common value auctions see Hendricks et al. (2008) and in private value auctions see Che et al. (2018). In these models it is possible that idiosyncratically strong firms may not want to join a group if they think that the benefits of forming a group are low.

[26] For an introduction to first-price sealed bid auction models, see, for example, Krishna (2009).

decisions on the other contracts and abstract in this way from strategic dynamic considerations. Thus, in the following, we focus on one contract that firms bid for and our notation suppresses an index for auctions.

Bidders are risk-neutral and their identities are known.[27] Firms can participate either as single bidders or as a bidding group. We denote each bidder or bidding group with $h$. The set of bidders submitting a bid is $\mathtt{N} = 1, ..., N$. Each bidder $h$ obtains an independent cost draw $c_h$ from a distribution $F_h$ with continuous density $f_h$ and support $[\underline{c}, \overline{c}] \subset R_+$. We assume that the cost draw of a bidding group is a function of the cost draws of its members would they have participated as single bidders, i.e., $c_h = \eta(c_i, c_j)$, where $i$ and $j$ are the members of the bidding group and $\eta$ is a function reflecting unobserved cost efficiencies of joining a bidder group.

The bidder with the lowest bid wins the contract and receives this bid. The bidding strategy $b_h = b_h(c_h; \mathtt{N})$ of bidder $h$ gives the optimal bid as a function of the cost draw $c_h$ and the set of competing bidders $\mathtt{N}$. Following Guerre et al. (2000), we write bidder $h$'s expected profit as

$$\pi_h(c_h; \mathtt{N}) = max_b(b - c_h) \prod_{k \in \mathtt{N} \setminus h} (1 - G_k(b; \mathtt{N})), \tag{1}$$

where $G_k(b; \mathtt{N}) = F_k(b_k^{-1}(b; \mathtt{N}))$, i.e., the probability of bidder $k$ to bid less than $b$, and $b_k^{-1}(b; \mathtt{N})$ $= c_k$. We focus on Bayesian-Nash equilibria in pure bidding strategies. The first order condition for bidder $h$ is then

$$\frac{1}{b_h - c_h} = \sum_{k \in \mathtt{N} \setminus h} \frac{g_k(b_h; \mathtt{N})}{(1 - G_k(b_h; \mathtt{N}))}, \tag{2}$$

which provides the basis for estimating bidders' cost distributions. An explicit solution to (2) does not exist, but, together with the boundary conditions that $b_h(\overline{c}; \mathtt{N}) = \overline{c}$ for all $h$, the equation uniquely characterizes optimal bidding strategies (Maskin and Riley, 2000). They show that in equilibrium, the bidders use a markup strategy and bid their values plus a shading factor that

[27] It is a useful simplifying assumption in the empirical auction literature to assume common knowledge of the set of actual bidders. Although only anecdotal, personal conversations with firms active in procurement construction suggest that it is suitable for our environment to assume that competitors are known before submitting a bid.

depends on the equilibrium behavior of opponents.[28,29]

## 5.2 Empirical approach

Based on the approaches of Guerre et al. (2000) and Krasnokutskaya (2011), we estimate the distribution of bids and account for unobserved heterogeneity. Our implementation relies on a parametric approach following Athey et al. (2011), Gugler et al. (2015a) and Gugler et al. (2015b). We assume that bids are Weibull-distributed and the unobserved heterogeneity $u$ is Gamma-distributed. Conditional on the observable auction characteristics $\mathtt{X}$ and bidder characteristics $\mathtt{Z}$, and the set of bidders' identities $\mathtt{N}$, the bid distribution of bidder $h$ is:

$$G_h(b_h|\mathtt{X},\mathtt{Z},u,\mathtt{N}) = 1 - \exp\left\{ - u\left(\frac{b_h}{\lambda_h(\mathtt{X},\mathtt{Z},\mathtt{N})}\right)^{\rho_h(\mathtt{X},\mathtt{Z},\mathtt{N})}\right\}, \tag{3}$$

where $\lambda_h(\mathtt{X},\mathtt{Z},\mathtt{N})$ is the scale and $\rho_h(\mathtt{X},\mathtt{Z},\mathtt{N})$ is the shape of the Weibull distribution. Both are parameterized by linear functions of $\lambda$ and $\rho$, i.e., $\lambda_h(\mathtt{X},\mathtt{Z},\mathtt{N}) = \lambda_0+\lambda_{\mathtt{X}}\mathtt{X}+\lambda_{\mathtt{Z}}\mathtt{Z}+\lambda_{\mathtt{N}}\mathtt{N}$ and $\rho_h(\mathtt{X},\mathtt{Z},\mathtt{N}) = \rho_0 + \rho_{\mathtt{X}}\mathtt{X} + \rho_{\mathtt{Z}}\mathtt{Z} + \rho_{\mathtt{N}}\mathtt{N}$. The component $u$ measuring unobserved auction specific heterogeneity has unit mean and variance $\theta$. We estimate (3) with maximum likelihood.

The set of observable auction characteristics $\mathtt{X}$ includes a dummy variable for heavy construction, a dummy variable for general contractor, a dummy variable for open procedure and the value of new orders, which is the countrywide monthly gross inflow of new contracts in the construction sector. We model bidder asymmetry with the set of bidder specific characteristics $\mathtt{Z}$. These include the backlog, the number of employees and the distance of a firm's address to the procurement site as well as the squares of these variables. If a single firm participates, we take the characteristics of this firm. If a bidding group participates, we calculate the mean backlog, the sum of the employees and the minimum distance using the values of the members of the bidding group. For both single bidders and bidding groups, we also calculate the mean backlog of the other firms as well as the sum of the size of other firms and the sum of the distance of the other firms that participate in the auction. We use these variables as proxies for the set of bidder identities $\mathtt{N}$, which also includes the

[28]The conditions for a unique equilibrium are provided in Maskin and Riley (2003) and Lebrun (2006).

[29]We assume that each potential bidder beliefs that upon entering she will observe at least one other bidder. This is a common assumption in the literature (e.g. Li and Zheng (2009)). In our sample, we do not observe auctions with only one single bidder.

log number of bidders participating in the auction.

Estimates of $G_k$ and the corresponding density function $g_k$, denoted by $\hat{G}_k$ and $\hat{g}_k$, permit calculation of the individual costs:[30]

$$\hat{c}_h = \phi_h(b_h; \mathtt{X}, \mathtt{Z}, \mathtt{N}) = b_h - \frac{1}{\sum_{k \in \mathtt{N} \setminus h} \frac{\hat{g}_k(b_h|\mathtt{X},\mathtt{Z},\mathtt{N})}{1-\hat{G}_k(b_h|\mathtt{X},\mathtt{Z},\mathtt{N})}}. \quad (4)$$

This gives a pseudo sample of bidders' costs depending on auction characteristics $\mathtt{X}$ and bidder characteristics $\mathtt{Z} = \mathtt{Z}_h$. For a bidding group, we obtain $\hat{c}_h = \eta(\hat{c}_i, \hat{c}_j, \mathtt{Z}_i, \mathtt{Z}_j)$, where $\hat{c}_i$ and $\hat{c}_j$ are the estimated cost draws of the group members would they have submitted single bids. $\mathtt{Z}_i$ and $\mathtt{Z}_j$ are the observed characteristics of these group members. Herewith, we are also able to model the cost efficiencies of a bidding group in the counterfactual analysis (see Section 7).

## 5.3 Endogenous Entry

As we are interested to know whether the members of the bidding groups would have submitted stand alone bids, it is important to consider the entry behavior of firms. We assume that bidders incur entry costs. Using the estimated distribution of bidders' costs, we now illustrate how we estimate bidders' entry cost based on observed entry behavior following Li and Zheng (2009), Krasnokutskaya and Seim (2011), and Athey et al. (2011). We assume private entry cost and that potential bidders do not draw their private cost until after entry, and we augment their approach to allow firms to form bidding groups as well.[31]

If participation is costly, then bidders' behavior can be modelled as a two stage decision process. First, each bidder incurs a cost $d_h$ to gather information and enter the auction with a single bid or a group bid. Once the entry cost $d_h$ is paid, bidder $h$ learns her cost for the construction site, $c_h$, and may bid in the auction. Actual bidders are denoted by the set $\mathtt{N}$; bidders acquiring information are called participants or potential bidders, and we denote the set of participants by $\mathtt{M}$, $\mathtt{N} \subseteq \mathtt{M}$ with $\mathtt{M} = 1, \ldots, M$. We defined the pool of potential bidders in Section 4.2.

[30] If one observes all bids and bidder identities, Li and Zhang (2015), Campo et al. (2003), and Laffont and Vuong (1996) show that the asymmetric independent private values model is identified.

[31] We opt for the more tractable model of nonselective entry, but acknowledge recent literature on selective entry, see e.g. Gentry and Li (2012), Roberts and Sweeting (2013) or Bhattacharya et al. (2014).

Bidder $h$'s ex ante expected profit from participating is

$$\Pi_h(p) = \sum_{\mathtt{N}\subseteq\mathtt{M}} \pi_h(\mathtt{N})Pr[\mathtt{N}|h \text{ enters, opponents play } p_{-h}] \tag{5}$$

where $p = (p_1, \ldots, p_M)$ is the profile of entry probabilities – either with a single bid or a group bid – and $\pi_h(\mathtt{N})$ is bidder $h$'s profit – either as a single bidder or as a group bidder – in the auction when N bidders participate. Entering the auction is optimal, if the expected profit $\Pi_h(p)$ exceeds the entry cost $d_h$. An asymmetric entry equilibrium ($p_{\mathtt{M}}$) exists, but in general it need not be unique (Li and Zhang, 2015).

Based on estimated bidders' costs, bidders' expected profits are:

$$\Pi_h(\mathtt{X},\mathtt{Z},\mathtt{W},\mathtt{N}) = \sum_{\mathtt{N}\subseteq\mathtt{M}} \pi_h(\mathtt{X},\mathtt{Z},\mathtt{N},\mathtt{M})Pr[\mathtt{N}|\mathtt{X},\mathtt{Z},\mathtt{W},\mathtt{M},h\in\mathtt{N}] \tag{6}$$

where $Pr[\mathtt{N}|\mathtt{X},\mathtt{Z},\mathtt{W},\mathtt{M},h\in\mathtt{N}]$ is the probability that N bidders enter given that $h$ enters. We augment this probability with additional variables W, described in detail below, that help us identify the formation of bidding groups. We use the sealed bid data to construct an estimate of bidders' beliefs about opponent entry. The distribution of bidder entry is binomial, as is the distribution of opponent entry. In particular, we specify

$$Pr[\mathtt{N}|\mathtt{X},\mathtt{Z},\mathtt{W},\mathtt{M},h\in\mathtt{N}] = \prod_{k\neq h\in\mathtt{N}\subseteq\mathtt{M}} p_k(\mathtt{X},\mathtt{Z},\mathtt{W},\mathtt{N}) \prod_{k\in\mathtt{M}\setminus\mathtt{N}} (1-p_k(\mathtt{X},\mathtt{Z},\mathtt{W},\mathtt{N})) \tag{7}$$

with a parametric specification of $p_k(\mathtt{X},\mathtt{Z},\mathtt{W},\mathtt{N})$, which we derive from a discrete choice model. Bidders choose to stay out of the auction, enter with a single bid or as a bidding group. We assume that bidders are able to form any bidding group with up to two members among all potential bidders. Depending on the number of potential bidders in an auction, this gives more than one million alternatives.[32]

[32] In our data, we observe bidding groups with up to five members. We treat bidding groups with more than two members as if they were a group of two. This assumption simplifies the analysis as it reduces the already large number of potential bidding groups, which have to be simulated. The number of observations in the conditional logit model is already large with this assumption. We have on average about 30 potential bidders in 2,054 auctions. While the single bidders make only a small part of the observations, the main mass of the observations comes from the potential

The corresponding discrete choice model describes the utility of bidding alone or joining a bidding group and is $u_k = \delta_k + \epsilon_k$. The deterministic part $\delta_k$ includes auction characteristics $\mathtt{X}$, firm characteristics $\mathtt{Z} = \mathtt{Z}_k$,[33] differences and changes in firm characteristics of group members $\mathtt{W} = \mathtt{W}_k$ that proxy synergies and identify group formation in our model, and $\mathtt{N}$. $\epsilon_k$ is the logit error. The entry probabilities can then be expressed as follows

$$p_k(\mathtt{X}, \mathtt{Z}, \mathtt{W}, \mathtt{N}) = \frac{\exp(\alpha_{\mathtt{X}}\mathtt{X} + \alpha_{\mathtt{Z}}\mathtt{Z}_k + \alpha_{\mathtt{W}}\mathtt{W}_k + \alpha_{\mathtt{N}}\mathtt{N})}{\sum_{m=1}^{\mathtt{M}} \exp(\alpha_{\mathtt{X}}\mathtt{X} + \alpha_{\mathtt{Z}}\mathtt{Z}_m + \alpha_{\mathtt{W}}\mathtt{W}_m + \alpha_{\mathtt{N}}\mathtt{N})} \tag{8}$$

where $m = 1, \ldots, \mathtt{M}$ covers all combinations of entry with a single bid and entry as an arbitrary bidding group with two members.[34] Differences in firm characteristics are, for example, the difference in firm size or distance to the procurement site of the two group members. These variables are set to zero for single bids. The changes in characteristics are the difference between own size, i.e., the number of employees, or distance, i.e., distance between a firm's location and the procurement site, to the group's size, i.e., sum of employees of group members, or distance, i.e., mean of distance of group members. The parameters of the model are estimated by maximum likelihood.

We assume that firms learn their cost draws after entry. In this way, we rule out that group formation depends on $\hat{c}_i$ of an individual firm. In particular, strong firms may make different decisions when it comes to group formation than weaker ones. This may be a concern as Hendricks et al. (2008) have shown in the context of common values and Che et al. (2018) in the context of bidding rings. By using equation 8 with a logit error $\epsilon_k$ that is iid across choices, we model the formation of bidding groups in a reduced form way. We exclude unobserved firm specific propensities to form bidding groups, because, for example, some firms are cash constrained and

group combinations. These are 30*29 combinations per auction times 2,054 auctions. From these combinations, we randomly choose one. So that only one combination without repetition remains. For example, when firm 1 has formed a bidding group with firm 2, firm 2 will not be allowed to form a bidding group with firm 1 anymore. We then arrive at 30*29/2*2,054=893,490 observations on average. The number of observations would exponentially increase, if we would allow for bidding groups with more members.

[33] As in the bidding model, these are backlog, firm size, and distance. In the case of a bidding group, we use the mean backlog, the sum of the employees and the minimum distance.

[34] We add from $m = 1$ onwards. The probability of no entry is given in equation 7. The set $\mathtt{M}$ includes bidders, either single bidders or bidding groups. In this way, we include all combinations of bidder groups consisting of bidders $i$ and $j$. However, as also in footnote 32 explained, we only allow for combinations without repetition. That means, when firm $i$ has formed a bidding group with firm $j$, firm $j$ will not be allowed to form a bidding group with firm $i$ anymore. And, if firm $i$ has formed a bidding group with firm $j$, firm $i$ will not be allowed to form a bidding group with firm $k$ anymore. If we index not bidders (either single bidders or group bidders), but firms, the summation in the denominator in equation 8 would be $\sum_{m_1=1}^{\mathtt{M}} \sum_{m_2=m_1}^{\mathtt{M}}$.

others are not. We proxy any synergies why firms form bidding groups with variables included in `W` also interacted with dummy variables for single bidders and group bidders, see also Table A.1. We also do not consider incentive constraints that could be related to group formation. For example, we do not model how the surplus is split. Our approach, however, assumes with a revealed preference argument that when group formation is observed it is more profitable than submitting a single bid. While overall our assumptions are restricting, we consider our approach as a first step to assess bidders' behavior when forming a bidding group.

# 6 Estimation results

In this section, we describe our estimation results for the bid distribution, and the entry model. We also describe the model fit and the estimated cost draws and markups.

## 6.1 Determinants of the bid distribution

Table 8 displays the estimation results of the determinants of the bid distribution using the Weibull-Gamma model. The estimated effect of the log of the number of bids is negative describing the effect of competition. Own distance (squared) and the distance of the other bidders measure firms' transport costs. The estimated coefficient of distance is positive, but diminishing with the square term. The total distance of other bidders in the auction also has a positive effect: if other firms are farther away from the project site, firms bid less aggressively.

The main determinant of the bid distribution is the engineer estimate. This estimate reflects the cost estimate of the project calculated by the engineers of the firm providing the data. In our model, it mainly describes the (size) heterogeneity across projects. While the log of the number of employees, our firm-specific size measure, is significant, other firms' size does not affect bids significantly. Neither own nor backlog of other firms are significant in this model. $\theta$, the parameter arising from the multiplicative random variable $u$ intended to capture unobserved heterogeneity between auctions, is also significant. Further included variables are auctions characteristics that control for the auction procedure, heavy construction, and if the bidder is a general contractor.

Table 8: Determinants of the distribution of bids – Weibull-Gamma

| Equation | Variable | Coefficient (1) | Standard error (2) |
|---|---|---|---|
| Scale $\lambda$ | Log number of bids | -5,981.38* | 2,626.67 |
| | Backlog | -453.56 | 424.32 |
| | Backlog squared | 137.31 | 159.65 |
| | Backlog others | 212.34 | 314.81 |
| | Number of employees | -.722 | .513 |
| | Number of employees squared | 7.74E5 | 5.24E12 |
| | Number of employees others | .510 | .254 |
| | Distance in km | 44.99** | 8.05 |
| | Distance in km squared | -.064** | .015 |
| | Distance in km others | 5.70* | 2.58 |
| | New orders | 1.11 | 4.70 |
| | Engineer estimate | .900** | .006 |
| | Heavy construction | 5,422.60 | 3,697.66 |
| | General contractor | 37,806.67** | 12,154.76 |
| | Open procedure | 5,422.12** | 1,512.16 |
| | Constant | -3,335.41 | 10,674.71 |
| Shape $\rho$ | New orders | 7.41E4** | 2.77E4 |
| | Engineer estimate | 3.04E-7** | 2.35E-8 |
| | Heavy construction | -.512** | .112 |
| | General contractor | 2.90** | .325 |
| | Open procedure | -.436** | .158 |
| | Constant | 6.70** | .497 |
| Variance $\theta$ | Constant | 2.44** | .075 |
| Observations | | | 14,803 |
| Wald chi2(15) | | | 31,485.93 |

Notes: Column (1) shows the coefficients estimated for the scale parameter $\lambda$ and for the shape parameter $\rho$ of the Weibull distribution of bids, and for unobserved heterogeneity, the Gamma distribution parameter $\theta$. *others* for the variables Backlog, Number of employees and Distance denotes the sum of the variable of the other bidders in the auction. $*$ ($**$) stands for significance at the 5% (1%) level.

## 6.2 Determinants of bidders' entry and formation of a bidding group

For the entry stage of our auction model we accommodate that firms can also form bidding groups. As outlined above, we model this decision process with a conditional logit choice model. First, this allows every bidder to explicitly choose whether to enter, submit a single bid or form a bidding group. Second, we introduce a choice possibility between different group partners. For the implementation of the partner choice in a bidding group, we had to limit the analysis to bidding groups of two firms. As outlined above that does not mean that we ignore bidding groups with more than two members, we treat them as if they were a bidding group of two.

Each firm can form a bidding group with another firm that is a potential bidder in the auction.

For every combination of a bidder pair in a specific auction, permutations are excluded randomly to avoid that the same group could enter twice within any auction. The variables distance (to the construction site, in km), number of employees and backlog as well as the dummy variables same postal code, same district, same state and same NUTS-3 code — all referring to the locations of the two bidders in the group — vary over a firm's choices within an auction, because each variable is modelled as being affected by the choice of partner firm. The number of employees of a bidding group is the sum of the number of employees of the group members. Distance and backlog of a bidding group are defined by the minimum and the mean of the group members' values. Table 9 shows summary statistics for group entrants, separated by groups participating and by groups determined as potential, but non-participating combinations.

Table 9: Summary statistics for group entrants

| | | Participation | | Potential bidders | |
|---|---|---|---|---|---|
| | | mean | s.d. | mean | s.d. |
| Groups | Number of obs. | 842 | | 968,901 | |
| | Employees | 3,892.06 | 3,591.75 | 1,609.45 | 3,011.10 |
| | Backlog | 0.100 | 0.654 | 0.088 | 0.641 |
| | Backlog change | 0.037 | 0.998 | -0.027 | 1.214 |
| | Distance (to construction site) | 142.37 | 92.29 | 124.31 | 83.72 |
| | Distance members | 173.44 | 136.46 | 170.80 | 123.60 |
| | Same postal members | 0.056 | 0.230 | 0.012 | 0.109 |
| | Same district members | 0.124 | 0.329 | 0.045 | 0.206 |
| | Same state members | 0.319 | 0.467 | 0.329 | 0.470 |
| | Same NUTS-3 members | 0.205 | 0.404 | 0.121 | 0.326 |

Notes: Summary statistics for actual and potential group bids in the conditional logit entry model. The single entrants — actual and potential — are the same as described in Table 3: Summary statistics under *Firms, Bidders*. The number of entering bidding groups is larger in the entry model compared to Table 3 (842 vs. 757) because it contains bids with at least one imputed covariate (mostly employees, which was imputed by a prediction relating the number of participations in auctions in the sample to the number of employees). Exclusion of entrants with missing values in the covariates would bias the entry model.

Table 10 reports selected results for the entry decision from the conditional logit estimation.[35] The estimation results show that own cost as measured by distance has an effect on firms' decision

[35] The estimation results for all variables are shown in Table A.1 in Appendix A. This table also shows the structure of the variables that are included in the entry model. Adding variables was done by using a simple strategy that included variables cumulatively, if the model calculation converged towards a solution; otherwise, the variable was not added to the model, and the next variable was added and tried to find a converging solution. Because each firm in each auction forms an individual choice situation, auction-specific variables do not vary within a choice and cannot be used as explanatory variables; after interacting these variables with the choice — single bidder or a general decision to bid with any other firm — they can be included. Note that interactions of explanatory variables with the single-bidder choice are necessary to generate variation in the choice predictions for a counterfactual where all group choices are assumed to be prohibited (see CF 3 and 4, below).

to enter auctions. Backlog and its square are significant, too. New orders in the construction sector overall decrease firms' probability to enter, implying that a higher level of demand in the industry leads firms to be less likely to bid in a (public) procurement auction.

Table 10: Determinants of bidders' entry and group formation – conditional logit model

| Variable | Coefficient (1) | Standard error (2) |
|---|---|---|
| Distance | -.00378** | .00055 |
| Backlog | 56.073** | 3.366 |
| Backlog squared | .23372** | .03766 |
| Employees | 1.89E-5 | 2.33E-5 |
| Employees squared | 4.81E-9** | 1.07E-9 |
| Backlog change | 28.195** | 1.682 |
| Distance members | -.04023** | .00078 |
| Distance members squared | 4.05E-5** | 1.00E-6 |
| Same postal members | .32801 | .20450 |
| Same district members | .17846 | .18608 |
| Same state members | -3.2470** | .11203 |
| Same NUTS-3 members | -.35011* | .16460 |
| Observations | 1,095,485 | |
| Pseudo R-squared | 0.7863 | |

Notes: Selected results for the entry decision from the conditional logit estimation. The estimation results for all variables are shown in Table A.1 in Appendix A. Choices of each potential entrant are: single-bid entry; bid with a second firm, chosen from the auction-specific set of potential bidders; and no bid. * $p < 0.05$, ** $p < 0.01$

## 6.3 Model fit

Table 11 shows the outcomes for bids and entry from the auctions compared to the fitted values of our model. Two samples are presented. Panel A shows the sample of all auctions. The mean observed bid is 2.310 million euro and the mean predicted bid is about the same with 2.302 million euro. The winning bid is less precisely predicted. While the observed winning bid is 2.048 million euro, the predicted winning bid is 1.916 million euro. The observed average number of bids is 7.6 and the predicted number of bids is 7.8. Panel B represents the subsample of bids where bidding groups participated. Again, the predictions for the bids are better than the predictions for the winning bids. The mean observed bid is 4.849 million euro and the mean predicted bid is about the same with 4.822 million euro. The observed winning bid is 4.349 million euro, while the predicted winning bid is 4.060 million euro. When assessing the entry model, the observed average number of bids as well as the predicted number of bids is 7.3.

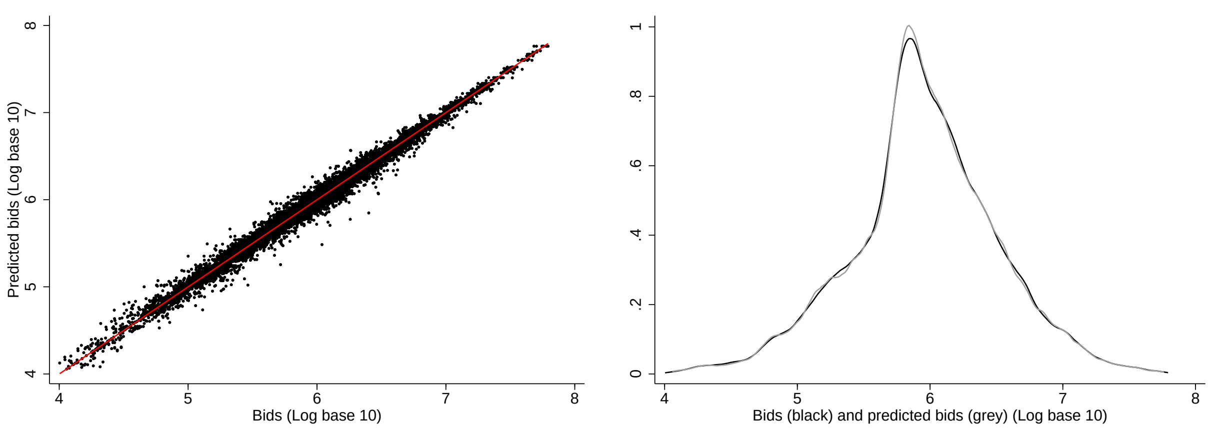
Table 11: Observed vs. fitted outcomes for bids and entry

| | | # of auctions | observed | predicted |
|---|---|---|---|---|
| Panel A. All auctions | Bid in million euro | 2,054 | 2.310 | 2.302 |
| | | | (3.921) | (0.024) |
| | Winning bid in million euro | | 2,048 | 1.916 |
| | | | (4.281) | (0.021) |
| | Number of bids | | 7.6 | 7.8 |
| | | | (3.17) | (0.050) |
| Panel B. Group participated | Bid in million euro | 533 | 4.849 | 4.822 |
| | | | (5.685) | (0.074) |
| | Winning bid in million euro | | 4.349 | 4.060 |
| | | | (6.366) | (0.065) |
| | Number of bids | | 7.3 | 7.3 |
| | | | (2.95) | (0.093) |

Notes: The numbers in parentheses below the means are the standard deviation in the sample and the standard deviation of the 5,000 draws for the fitted values.

The results depicted in Table 11 show that our empirical model predicts reasonably well on average. To assess the predictive power of our empirical model further, we show a scatter plot of actual and predicted bids as well as kernel densities of actual and predicted bids in Figure 1. This comparison shows that also the distributions of observed and predicted bids are reasonably similar and that there are only smaller deviations.

Figure 1: Predicted bids

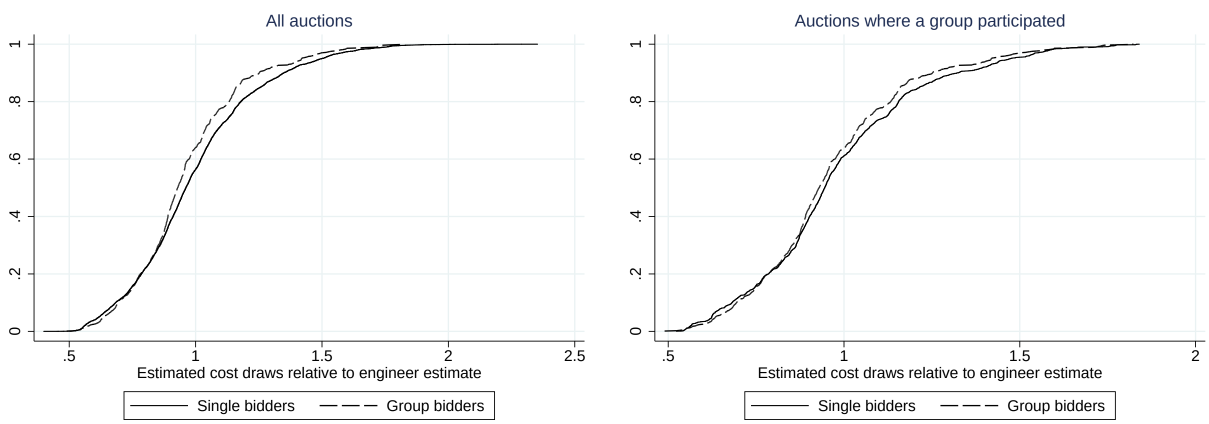



Notes: The left graph shows a scatter plot of actual (horizontal) vs. predicted (vertical) bids, and the identity line in red. The right graph shows kernel densities of actual (black) and predicted (grey) bids. All scales are in log base 10 of 2006 Euros.

## 6.4 Estimated cost draws and markups

Our bidding model allows for asymmetric cost distributions. In Figure 2, we show the cumulative distribution of the estimated cost draws $\hat{c}_h$ (see Equation 4) of single bidders (solid line) and group bidders (dashed line) for all auctions (left graph) and for auctions where bidding groups participated (right graph). To account for observed auction heterogeneity, we calculate the ratio of the cost draw to the engineer estimate. We observe that group bidders have lower cost draws than single bidders indicating cost efficiencies resulting from forming a bidding group. When we compare the distributions of single bidders and group bidders using a Kolmogorov-Smirnov test, we find that the two distributions are significantly different from each other in the sample with all auctions (p=0.000), and are not significantly different from each other in the sample of auctions where bidding groups participated (p=0.147).

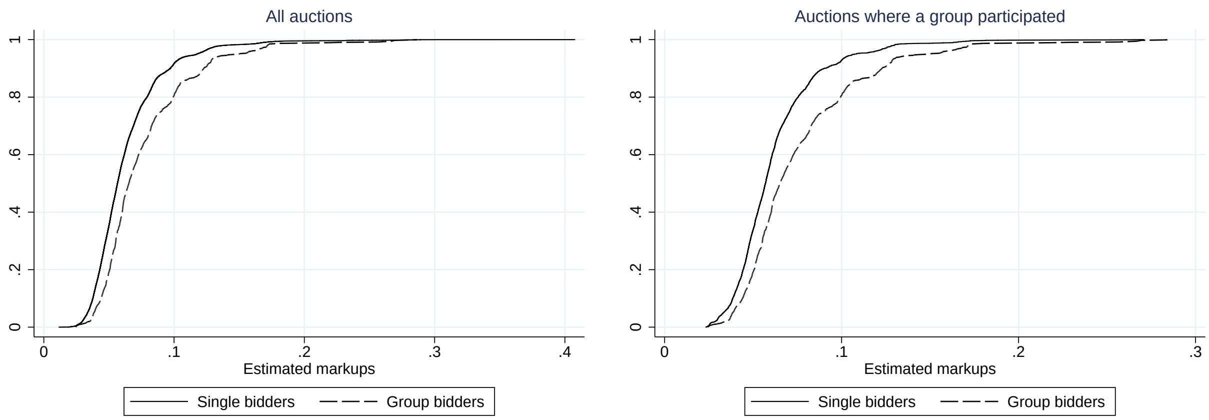
Figure 2: Cumulative distribution of estimated cost draws




Notes: The graph shows the cumulative distribution of the estimated cost draws of single bidders (solid line) and group bidders (dashed line). The left graph is based on the sample of all auctions; the right graph on the auction sample where a group participated. Estimated cost draws are divided by the engineer estimate.

In Figure 3, we show the distribution of estimated markups calculated as difference between simulated bids and estimated cost draws over simulated bids. Again, we show the estimated markups of single bidders (solid line) and group bidders (dashed line) for the sample of all auctions (left graph) and for the sample where a group participated (right graph). We find that group bidders have higher markups than single bidders. Using a Kolmogorov-Smirnov test, we find that the two distributions are significantly different from each other in both samples (p=0.000).

Figure 3: Cumulative distribution of estimated markups




Notes: The graph shows the cumulative distribution of the estimated markups of single bidders (solid line) and group bidders (dashed line). The left graph is based on the sample of all auctions; the right graph on the auction sample where a group participated. Estimated markups are the difference between simulated bids and estimated cost draws over simulated bids.

# 7 Counterfactual analysis

We run two types of counterfactual analysis. In Section 7.1, we investigate the effect of prohibiting bidding groups on winning bids and the number of bidders. In Section 7.2, we analyze the effects of restricting bidding groups to small firms or allowing bidding groups only when a small firm participates. For both counterfactual analyses, we calculate the outcomes with an exogenously fixed number of bidders and allowing for endogenous entry in the bidding process. Finally, Section 7.3 compares the distribution of small and large firms in all counterfactual scenarios.

## 7.1 Prohibition of bidding groups

Our first type of counterfactual analysis is a comparison of the current practice of permitting bidding groups to an alternative policy of forbidding bidding groups outright. The motivation to ban bidding groups is to preclude any anti-competitive effects in advance that may come along with the formation of bidding groups. To assess the effects of a prohibition of bidding groups, we run two sets of counterfactuals. The first set assumes that entry is exogenously given and the second set allows for endogenous entry of bidders. Each set of counterfactuals consists of two scenarios. In the first scenario, the members of the bidding group are not allowed to participate and submit a single bid once the bidding group is prohibited. In the second scenario, the members of the now prohibited bidding group are allowed to participate and submit a single bid. This gives four counterfactuals and for each we calculate bids, winning bids and the number of bids.

When we dissolve a bidding group, we assume that the cost efficiencies result from distance, firm size measured by employees and backlog. Thus, we replace the group values of distance, employees and backlog for the individual values of each member of the bidding group. We observe changes in the number of bidders, size of the other firms, distance of other firms and backlog of other firms. There is also a change in cost as (own) size, distance and backlog are changing.[36] Each entrant — single or in a group — obtains a fitted entry probability in the entry model.[37] Entry probabilities are re-calculated based on the adjusted covariates and these counterfactual-specific entry probabilities are used in the simulations of the counterfactuals. For the adjusted entry sets, bids are then drawn again from the fitted bid distribution in line with the covariates of the entrants.

The two scenarios outlined above are two extremes. The first scenario, where all members of a bidding group are allowed to submit a bid, implies that without the bidding group, no individual group member would have been able to submit a stand-alone bid. This counterfactual excludes all firms that were members of the bidding group from participation, and corresponds to the most extreme interpretation of the law on bidding groups under which firms must be unable to submit any bid to make their participation in a bidding group legal. In the second scenario, the opposite viewpoint is taken: again we exclude bidding groups from potential entrants, but allow all group members to submit stand-alone bids. Group members face no restrictions on entry and bidding in our model except for the possibility of disadvantageous values of their observable characteristics, as included in the bid distribution estimation — e.g. backlog, distance, size, etc. In our interpretation, this represents the opposite extreme position of group formation motives: group members could bid individually given their covariates, but cannot form a bidding group to benefit from anti-competitive

[36] For example, when a bidding group is dissolved the distance of other bidders is changing for all bidders. If the members are also allowed to bid, the own distance to the project site of at least one member is also changing as we assume that distance to the project site of the bidding group is the minimum distance of all members.

[37] 5,000 repetitions are made of random draws to obtain a combination of entrants for each auction according to the fitted entry probabilities. After entering, each chosen entrant obtains a bid draw. For the counterfactuals, the set of entrants is adjusted in the way intended by a counterfactual. For example, in counterfactual 3, where no group bids are allowed and single bids of the group members assumed to be impossible, only the set of potential bidders without those bidders is used. Then, the covariates are adjusted, which affects the number of potential bidders, and the variables that are based on the covariates of all other potential bidders for the auction (sum of distance of other potential bidders, sum of others' backlogs, sum of others' employees), and their interactions in the entry model.

effects by reducing the number of potential and/or actual bidders.

We show the results of the four counterfactuals for the sample where groups participated in Table 12. The entries for bid and winning bids are percentage changes relative to the simulation results. For the number of bids, the values are in unit changes. The significance levels are from tests of mean differences of the bids/winning bids/number of bids between the simulation and each counterfactual on the auction level.

Table 12: Prohibiting bidding groups

| | | exogenous entry (bids only) | | endogenous entry (+ entry model) | |
|---|---|---|---|---|---|
| | | single bids are possible | | single bids are possible | |
| | | no | yes | no | yes |
| | | [CF 1] | [CF 2] | [CF 3] | [CF 4] |
| Group participated | Bid | -0.06** | 0.01 | -0.05** | -0.03** |
| (# of auctions = 492) | | (0.0073) | (0.0066) | (0.0078) | (0.0068) |
| | Winning bid | 3.80** | -2.83** | 2.34** | 2.14** |
| | | (0.3249) | (0.2084) | (0.2365) | (0.2438) |
| | Number of bids | -1.51** | 1.74** | -0.39** | -0.16* |
| | | (0.0384) | (0.0507) | (0.0640) | (0.0679) |

The entries for bid and winning bids are percentage changes relative to the simulation results. For the number of bids, the values are in bidder unit changes. Auctions where only groups participated are excluded, because they drop out of CF 1 by construction. For comparability of the samples, these auctions are excluded also in all other counterfactuals. $*$ ($**$) stands for significance at the 5% (1%) level.

As the results for the counterfactual analysis in the two samples are rather similar, we focus on the first sample (group participated). In our first counterfactual (CF 1), we calculate bids, winning bids and the number of bids assuming no bidding group was formed and the bidders of the bidding group are not allowed to submit a single bid. This would reflect a situation where members of a bidding group are only able to enter as a group, but not as single bidders. Column (1) of Table 12, shows that the winning bids would increase by 3.8 percent, when we forbid bidding groups, and members do not submit single bids. This is the result of a mechanical reduction in the number of participants by 1.51. The second counterfactual (CF2) shows the opposite effect when all members of the bidding group would submit a single bid. As depicted in column (2), the winning bid would decrease by 2.8 percent as the number of bidders mechanically increases by 1.74. These numbers provide the two extreme cases from dissolving bidding groups with the number of bidders given exogenously.

Turning now to the results in columns (3) and (4) of Table 12, where we account for endogenous entry in the bidding process, the winning bids would increase by about 2.3 and 2.1 percent, and the number of bidders would decrease by 0.39 and 0.16, respectively, if bidding groups are prohibited. Once bidding groups are dissolved and group members as well as other firms in the set of potential bidders reconsider their entry decisions, the reduction in the number of bidding groups is not fully offset by other potential bidders. Thus, the winning bids would increase. We also observe that whether we allow members of the bidding group to submit single bids or not (the difference between columns (3) and (4)) does not change the results very much.

The fact that the number of bids in the counterfactual scenario of forbidding bidding groups would only change by -0.16 also implies that the market power effect due to bidding groups is rather small. The reasons are (1) that the number of observed bids (on average more than 7) is rather high in Austria so that competitive pressure is high and bidding groups are formed mainly for efficiency reasons; and (2) that the number of potential bidders is high (around 30) so that counterfactual entry is high. The main reason for observing more than two percent higher bids in the scenario of forbidding bidding groups is that the counterfactually entering firms are less efficient than actual bidding groups.

Summarizing, forbidding bidding groups when accounting for endogenous entry would reduce the number of bidders only slightly but would increase the winning bid by more than 2%. The (main) reason is entry of inefficient firms.

### 7.2 Policy to support small firms

In the next policy experiment, we ask if small firms would benefit from a policy that demands that i) only small firms may form bidding groups, or ii) a small firm must be part of a permissible bidding group. This could enhance entry, if the covariates of small firms capture a handicap to enter auctions, in particular for large and complex projects. We define small and large firms by fixing a threshold of 30 employees that reflects the median size for all firms in the sample. We again run two sets of counterfactuals, and distinguish between exogenous and endogenous entry. For each set, we consider two scenarios. In the first scenario the larger firms that have been in a bidding group are not allowed to submit single bids (CF 5 and CF 7), in the second scenario they have no restrictions to bid alone (CF 6 and CF 8).

Columns (1) and (2) of Table 13, depict the results when only small firms are allowed to form bidding groups. In Columns (3) and (4), at least one small firm must be member of a bidding group. The results in Column (1) show that the winning bids increase by 2.4 percent, when only small firms may form bidding groups and we do not allow large firms that have been in a bidding group to submit single bids. The number of bidders would decrease by 0.39. The results are slightly less pronounced, when single bids by larger firms are possible as column (2) shows. The winning bid would increase by 2.2 percent and the number of bidders would decrease by 0.15.

Table 13: Small firm policy

| | | Only small firms single bids are possible | | At least one small firm single bids are possible | |
|---|---|---|---|---|---|
| | | no [CF 5] | yes [CF 6] | no [CF 7] | yes [CF 8] |
| Group participated (# of auctions=492) | Bid | -0.03** | -0.02* | -0.04* | -0.03** |
| | | (0.0075) | (0.0070) | (0.0150) | (0.0084) |
| | Winning bid | 2.37** | 2.16** | 2.25** | 2.05** |
| | | (0.2415) | (0.2463) | (0.2330) | (0.2358) |
| | Number of bids | -0.39** | -0.15* | -0.36** | -0.13 |
| | | (0.0639) | (0.0679) | (0.0626) | (0.0665) |

Notes: The entries for bid and winning bids are percentage changes relative to the simulation results. For the number of bids, the values are in bidder unit changes. $*$ ($**$) stands for significance at the 5% (1%) level.

Turning to the results in columns (3) and (4) of Table 13, bidding groups can enter when at least one small firm is participating. Winning bids would increase by about 2.25 and 2.05 percent and the number of bidders would decrease by 0.36 and 0.13. Allowing larger firms in the bidding groups to submit single bids does not change the results very much.

Summarizing, allowing only small firms to form bidding groups or demanding at least one small firm in the bidding group – accounting for endogenous entry – would reduce the number of bidders slightly and increase the winning bid by more then 2%. Thus, bidding groups involving two large firms appear to provide the most efficient outcomes.

### 7.3 Prevalence of large and small firms

Finally, to assess the effect of the various counterfactuals on small firms, we now compare the prevalence of large and small firms for all scenarios. Table 14 shows the total number of bidders broken down into the number of small bidders and the number of large bidders. As a point of reference, we show the predicted number of bidders based on the observables from our model in Column (1). In all counterfactuals small firms would benefit — in the sense that more small firms would participate crowding out large firms in public procurement auctions — from prohibiting bidding groups or from allowing only bidding groups that must involve at least one small firm. The first order effects are, however, a reduced number of bidders and a higher price. The auctioneer (i.e. the consumer/the state/the taxpayer), thus, would prefer to not prohibit bidding groups. Implicit small firm subsidies (such as a de minimis rule) do not appear to be warranted.

Table 14: Distribution of firms

| | (1)<br>Entry | (2)<br>CF 3 | (3)<br>CF 4 | (4)<br>CF 5 | (5)<br>CF 6 | (6)<br>CF 7 | (7)<br>CF 8 |
|---|---|---|---|---|---|---|---|
| Small bidders | 0.46 | 0.53 | 0.53 | 0.53 | 0.53 | 0.53 | 0.53 |
| Large bidders | 6.96 | 6.47 | 6.71 | 6.47 | 6.71 | 6.49 | 6.73 |
| Total | 7.42 | 6.99 | 7.23 | 7.00 | 7.24 | 7.02 | 7.26 |

Notes: The entries contain the change in the simulated number of small and large bidders. A small firm is defined as having less than 30 employees, which is the median number of employees for all firms in the sample.

## 8 Conclusions

We analyzed bidding groups that participate in procurement auctions and investigated the effects of bidding groups on winning bids and bidders' participation. We asked, whether, in the absence of the joint bid, there would have been two or more independent bids, and whether these bids would yield a different final outcome. Using data from the construction sector in Austria, we estimated a static bidding model of first-price auctions that accounts for endogenous entry and unobserved heterogeneity. We simulated and evaluated bidding groups and their entry behavior with the aim to run policy relevant counterfactuals.

Our results indicate that the auctioneer does not benefit from a policy of forbidding bidding groups nor from a policy that requires small firms to be part of a bidding group. When we account for endogenous entry, we find that although participation would decrease only slightly, winning bids would increase by about two percent. When bidding groups are forbidden outright, only small firms are allowed to form bidding groups or when bidding groups must involve at least one small firm, then fewer large firms take part in public procurement auctions, and other firms — less efficient firms — enter in the bidding process. The reason is that for many public procurement projects — large and complex projects — it would be most efficient if two larger firms combine forces.

Our results stress the pro-competitive effects of joint bidding on average. In our context, the optimal policy would be to not forbid them and to not confine them to small firms. However, our results hinge on the facts that the number of observed bids (on average more than 7) and the number of potential bidders (around 30) are rather high in Austria. Therefore, competitive pressure and counterfactual entry are high. Authorities should therefore make sure that the public procurement process is transparent and non-discriminatory, and that market entry barriers are low.

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# A Appendix: Tables

To calculate a parametric version of $p_k(\mathtt{X},\mathtt{Z},\mathtt{N})$ in Equation 7, we estimate a discrete choice model. For the implementation, see Equation 8. Bidders have multiple choices: they can choose to stay out of the auctions, enter with a single bid or as a bidding group with two members. We include as explanatory variables auction characteristics $\mathtt{X}$, bidder characteristics $\mathtt{Z}$, differences in firm characteristics of group members, $\mathtt{Z}_1^k$, and changes in firm characteristics $\mathtt{Z}_2^k$. As explained earlier, we define differences in firm characteristics of group members, for example, by the difference in firm size or distance to the procurement site of the two group members. These variables are set to zero for single bids. We define the changes in characteristics as the difference between own size, i.e., the number of employees, or distance, i.e., distance between a firm's location and the procurement site, to the group's size, i.e., sum of employees of group members, or distance, i.e., mean of distance of group members. Below we show the detailed estimation results from this model.

Table A.1: Determinants of bidders' entry and group formation

| Variable | Lambda | Std. err. | Rho | Std. err. |
|---|---|---|---|---|
| 1(single bidder) × Distance | -.008248 | .0003168 | -26.03 | 0.000 |
| 1(single bidder) × Backlog | .0139985 | .0217894 | 0.64 | 0.521 |
| 1(single bidder) × Employees | .0005684 | .0000108 | 52.82 | 0.000 |
| 1(single bidder) × Employees squared | -1.09e-08 | 3.97e-10 | -27.37 | 0.000 |
| Distance | -.0037874 | .0005524 | -6.86 | 0.000 |
| Backlog | 56.07311 | 3.366032 | 16.66 | 0.000 |
| Employees | .0000189 | .0000233 | 0.81 | 0.419 |
| Employees squared | 4.81e-09 | 1.07e-09 | 4.52 | 0.000 |
| 1(single bidder) × Engineer estimate | 1.02e-06 | 1.03e-07 | 9.95 | 0.000 |
| 1(single bidder) × New orders | .0000276 | .0000634 | 0.44 | 0.663 |
| 1(single bidder) × Heavy construction | .0657311 | .0332349 | 1.98 | 0.048 |
| 1(single bidder) × General contractor | -.3669496 | .0643668 | -5.70 | 0.000 |
| 1(single bidder) × Open procedure | .4981065 | .0366498 | 13.59 | 0.000 |
| 1(single bidder) × Log(Potential bidders) | -.2665107 | .0410771 | -6.49 | 0.000 |
| 1(group bidder) × Engineer estimate | -3.58e-06 | 3.45e-07 | -10.37 | 0.000 |
| 1(group bidder) × Heavy construction | 1.152395 | .1080961 | 10.66 | 0.000 |
| 1(group bidder) × General contractor | -1.040628 | .307923 | -3.38 | 0.001 |
| 1(group bidder) × Open procedure | -3.025966 | .1037179 | -29.17 | 0.000 |
| 1(single bidder) × Backlog squared | -.0321124 | .0115652 | -2.78 | 0.005 |
| 1(single bidder) × Backlog others | -.0000481 | .0000812 | -0.59 | 0.554 |
| 1(single bidder) × Employees others | -3.63e-07 | 5.69e-08 | -6.38 | 0.000 |
| 1(single bidder) × Distance squared | .0000107 | 6.71e-07 | 15.99 | 0.000 |
| 1(single bidder) × Distance others | -2.48e-07 | 5.50e-07 | -0.45 | 0.652 |
| 1(group bidder) × Backlog | -.0026085 | .0644269 | -0.04 | 0.968 |
| Backlog change | 28.19515 | 1.682335 | 16.76 | 0.000 |
| Backlog squared | .2337191 | .0376615 | 6.21 | 0.000 |
| 1(single bidder) × Engineer estimate × Distance | 1.83e-09 | 1.53e-10 | 11.95 | 0.000 |
| 1(group bidder) × Engineer estimate × Distance | 1.46e-09 | 4.33e-10 | 3.38 | 0.001 |
| 1(single bidder) × Engineer estimate × Backlog | 5.07e-09 | 1.05e-08 | 0.48 | 0.630 |
| 1(group bidder) × Engineer estimate × Backlog | 2.24e-08 | 2.28e-08 | 0.98 | 0.326 |
| 1(single bidder) × Engineer estimate × Employees | -2.22e-11 | 4.66e-12 | -4.77 | 0.000 |
| 1(group bidder) × Engineer estimate × Employees | 1.06e-10 | 1.22e-11 | 8.69 | 0.000 |
| 1(single bidder) × Engineer estimate × Backlog squared | 4.78e-09 | 6.36e-09 | 0.75 | 0.452 |

| | | | | |
|---|---|---|---|---|
| 1(group bidder) × Engineer estimate × Backlog squared | 1.47e-08 | 1.82e-08 | 0.81 | 0.418 |
| 1(single bidder) × Engineer estimate × Backlog others | 1.62e-12 | 5.38e-11 | 0.03 | 0.976 |
| 1(group bidder) × Engineer estimate × Backlog others | -4.03e-11 | 9.49e-11 | -0.42 | 0.671 |
| 1(single bidder) × Engineer estimate × Employees squared | 5.67e-16 | 1.47e-16 | 3.85 | 0.000 |
| 1(group bidder) × Engineer estimate × Employees squared | -5.85e-15 | 1.09e-15 | -5.34 | 0.000 |
| 1(single bidder) × Engineer estimate × Employees others | 5.29e-14 | 3.70e-14 | 1.43 | 0.152 |
| 1(group bidder) × Engineer estimate × Employees others | -8.54e-14 | 6.71e-14 | -1.27 | 0.203 |
| 1(single bidder) × Engineer estimate × Distance squared | -2.69e-12 | 3.60e-13 | -7.45 | 0.000 |
| 1(group bidder) × Engineer estimate × Distance squared | -3.19e-12 | 1.02e-12 | -3.12 | 0.002 |
| 1(single bidder) × Engineer estimate × Distance others | 1.40e-12 | 3.95e-13 | 3.56 | 0.000 |
| 1(group bidder) × Engineer estimate × Distance others | 1.42e-12 | 6.93e-13 | 2.04 | 0.041 |
| 1(single bidder) × Engineer estimate squared | -3.54e-14 | 5.89e-15 | -6.02 | 0.000 |
| 1(group bidder) × Engineer estimate squared | 1.63e-13 | 1.60e-14 | 10.22 | 0.000 |
| 1(single bidder) × Engineer estimate squared × Distance | -5.11e-17 | 5.96e-18 | -8.56 | 0.000 |
| 1(single bidder) × Engineer estimate squared × Backlog | 2.53e-16 | 5.06e-16 | 0.50 | 0.617 |
| 1(single bidder) × Engineer estimate squared × Employees | 5.94e-19 | 1.92e-19 | 3.08 | 0.002 |
| 1(single bidder) × Engineer estimate squared × Backlog squared | -4.81e-16 | 3.28e-16 | -1.47 | 0.143 |
| 1(single bidder) × Engineer estimate squared × Backlog others | 2.94e-19 | 3.44e-18 | 0.09 | 0.932 |
| 1(single bidder) × Engineer estimate squared × Employees squared | -1.77e-23 | 6.75e-24 | -2.62 | 0.009 |
| 1(single bidder) × Engineer estimate squared × Employees others | -8.75e-22 | 1.95e-21 | -0.45 | 0.653 |
| 1(single bidder) × Engineer estimate squared × Distance squared | 7.75e-20 | 1.39e-20 | 5.59 | 0.000 |
| 1(single bidder) × Engineer estimate squared × Distance others | -6.82e-20 | 2.97e-20 | -2.30 | 0.022 |
| 1(group bidder) × Engineer estimate squared × Distance | -6.48e-17 | 1.71e-17 | -3.80 | 0.000 |
| 1(group bidder) × Engineer estimate squared × Backlog | -2.37e-16 | 1.02e-15 | -0.23 | 0.816 |
| 1(group bidder) × Engineer estimate squared × Employees | -4.29e-18 | 5.48e-19 | -7.83 | 0.000 |
| 1(group bidder) × Engineer estimate squared × Backlog squared | -8.34e-16 | 9.21e-16 | -0.91 | 0.365 |
| 1(group bidder) × Engineer estimate squared × Backlog others | -2.55e-18 | 5.44e-18 | -0.47 | 0.639 |
| 1(group bidder) × Engineer estimate squared × Employees squared | 2.44e-22 | 4.85e-23 | 5.04 | 0.000 |
| 1(group bidder) × Engineer estimate squared × Employees others | 5.32e-21 | 3.37e-21 | 1.58 | 0.114 |
| 1(group bidder) × Engineer estimate squared × Distance squared | 1.37e-19 | 3.26e-20 | 4.21 | 0.000 |
| 1(group bidder) × Engineer estimate squared × Distance others | -6.68e-20 | 4.28e-20 | -1.56 | 0.119 |
| 1(single bidder) × Engineer estimate × New orders | -9.47e-11 | 3.44e-11 | -2.75 | 0.006 |
| 1(group bidder) × Engineer estimate × New orders | -2.39e-11 | 6.11e-11 | -0.39 | 0.696 |
| 1(single bidder) × Engineer estimate squared × New orders | 2.96e-18 | 1.69e-18 | 1.75 | 0.081 |
| 1(group bidder) × Engineer estimate squared × New orders | 8.38e-19 | 3.14e-18 | 0.27 | 0.790 |
| 1(single bidder) × Engineer estimate × Heavy construction | -5.47e-08 | 1.75e-08 | -3.13 | 0.002 |
| 1(group bidder) × Engineer estimate × Heavy construction | -1.56e-07 | 3.77e-08 | -4.14 | 0.000 |
| 1(single bidder) × Engineer estimate squared × Heavy construction | 1.46e-15 | 1.01e-15 | 1.44 | 0.150 |
| 1(group bidder) × Engineer estimate squared × Heavy construction | 5.73e-15 | 2.10e-15 | 2.73 | 0.006 |
| 1(single bidder) × Engineer estimate × General contractor | -3.59e-08 | 2.30e-08 | -1.56 | 0.118 |
| 1(group bidder) × Engineer estimate × General contractor | -9.07e-08 | 6.21e-08 | -1.46 | 0.144 |
| 1(single bidder) × Engineer estimate squared × General contractor | 1.93e-15 | 1.17e-15 | 1.65 | 0.099 |
| 1(group bidder) × Engineer estimate squared × General contractor | 5.49e-15 | 2.67e-15 | 2.05 | 0.040 |
| 1(single bidder) × Engineer estimate × Open procedure | -1.63e-07 | 3.08e-08 | -5.30 | 0.000 |
| 1(group bidder) × Engineer estimate × Open procedure | 4.53e-06 | 2.64e-07 | 17.16 | 0.000 |
| 1(single bidder) × Engineer estimate squared × Open procedure | 6.16e-15 | 2.19e-15 | 2.81 | 0.005 |
| 1(group bidder) × Engineer estimate squared × Open procedure | -1.93e-13 | 1.14e-14 | -16.86 | 0.000 |
| 1(single bidder) × Engineer estimate × Log(Potential bidders) | -2.93e-07 | 3.49e-08 | -8.38 | 0.000 |
| 1(group bidder) × Engineer estimate × Log(Potential bidders) | -3.30e-07 | 7.06e-08 | -4.67 | 0.000 |
| 1(single bidder) × Engineer estimate squared × Log(Potential bidders) | 9.62e-15 | 2.20e-15 | 4.38 | 0.000 |
| 1(group bidder) × Engineer estimate squared × Log(Potential bidders) | 1.04e-14 | 3.75e-15 | 2.77 | 0.006 |
| Distance members | -.0402251 | .0007765 | -51.80 | 0.000 |
| Distance members squared | .0000405 | 1.00e-06 | 40.49 | 0.000 |
| Distance members × Employees | 1.86e-07 | 2.40e-08 | 7.73 | 0.000 |
| Same district members | .1784625 | .1860788 | 0.96 | 0.338 |
| Same state members | -3.24702 | .1120286 | -28.98 | 0.000 |
| Same NUTS-3 members | -.3501098 | .1645972 | -2.13 | 0.033 |
| Same postal members | .3280106 | .204504 | 1.60 | 0.109 |
| Engineer estimate × Distance members | 2.79e-09 | 2.75e-10 | 10.15 | 0.000 |
| Engineer estimate × Distance members squared | -2.63e-12 | 3.84e-13 | -6.85 | 0.000 |
| Engineer estimate squared × Distance members | -6.36e-17 | 1.12e-17 | -5.70 | 0.000 |
| Engineer estimate squared × Distance members squared | 5.96e-20 | 1.24e-20 | 4.82 | 0.000 |
| Observations | 1,095,485 | | | |
| Pseudo R-squared | 0.7863 | | | |