Discussion papers of the Max Planck Institute for Research on Collective Goods Bonn 2018/5

Debarment and Collusion in Procurement Auctions

Claudia Cerrone
Yoan Hermstrüwer
Pedro Robalo

MAX PLANCK SOCIETY

Discussion papers of the
Max Planck Institute
for Research on Collective Goods

Bonn 2018/5

Debarment and Collusion in Procurement Auctions

Claudia Cerrone / Yoan Hermstrüwer / Pedro Robalo

April 2018

Revised version: February 2020

Max Planck Institute for Research on Collective Goods, Kurt-Schumacher-Str. 10, D-53113 Bonn
http://www.coll.mpg.de

Debarment and Collusion in Procurement Auctions*

Claudia Cerrone† Yoan Hermstrüwer‡ Pedro Robalo§

Abstract

This article presents the first experiment exploring the impact of debarments – the exclusion of colluding bidders – on collusion in procurement auctions. We find that debarments reduce collusion and bids relative to a market with no sanction. The deterrent effect of debarments increases in their length. However, shorter debarments reduce efficiency and increase the bids of non-debarred bidders. This suggests that debarments that are too lenient may trigger tacit collusion among the bidders who remain in the market, thereby facilitating the very behavior they aim to deter.

JEL codes: C92, D03, D44, K21, K42.

Keywords: debarment, collusion, procurement auctions, sanctions.

*We thank Phil Brookins, Christoph Engel, Vitali Gretschko, Oliver Kirchkamp, Nathan Maddix, Sander Onderstal, Gyula Seres, and conference participants at the 29th Annual Meeting of the American Law and Economics Association at Boston University (ALEA 2018), at the 2nd Conference on Empirical Legal Studies in Europe at KU Leuven (CELSE 2018), and at the 2019 INFORMS Annual Meeting in Seattle (INFORMS 2019) for helpful comments. Funding from the Max Planck Society is gratefully acknowledged.

†E-mail: cerrone@coll.mpg.de Address: Max Planck Institute for Research on Collective Goods, Kurt-Schumacher-Str. 10, 53113, Bonn, Germany.

‡E-mail: hermstruewer@coll.mpg.de Address: Max Planck Institute for Research on Collective Goods, Kurt-Schumacher-Str. 10, 53113, Bonn, Germany.

§E-mail: pedro.robalo@concorrencia.pt Address: Portuguese Competition Authority, Av. de Berna 19, 1050-037 Lisboa, Portugal.

1 Introduction

Collusion is a pervasive phenomenon in public procurement auctions. The public provision of infrastructure, education and pharmaceuticals is particularly vulnerable to the concomitant harms of collusion, i.e. reduced competition and an increase in the cost of public projects. In order to prevent a wasteful use of taxpayer money, governments and international organizations devote substantial resources to the fight against collusion using different remedies.

One of the most important remedies used in reaction to collusion and other types of illegal practices in procurement auctions is debarment. Debarment denotes the exclusion of bidders who have engaged in collusion or other illegal practices from future procurement auctions for a specified period of time. Enacted as administrative remedies by the US Congress in 1884 with no deterrence function, debarments were later used by governments and international development banks, such as the World Bank, as sanctions with a clear deterrence purpose. Between 2007 and 2015, the World Bank debarred more than 360 companies and individuals (World Bank 2015), with debarments accounting for 93 % of all sanctions (Fariello and Bo 2015). In 2016, for instance, the World Bank debarred Schneider Electric Pakistan Pvt. Limited for 25 months for engaging in collusive practices under the Pakistan Electricity Distribution and Transmission Improvement Project.[1]

Despite their widespread use, evidence on the effects of debarments remains scarce. The only existing study on debarments is theoretical and focuses on their effect on corruption (Auriol and Søreide 2017). The study shows that debarments will effectively deter corruption in small markets if the probability of debarment is sufficiently high and if bidders sufficiently value contract awards in future procurement auctions.[2] However, there is no empirical evidence on the effect of debarments, the main reason being that collusion is difficult to detect in practice. Given these constraints, experiments, as the one presented in this article, are particularly

1. The debarred entity was the member of a bidding ring of switchgear manufacturers who had agreed in advance on winning bids in procurement auctions in Pakistan.

2. This finding is consistent with the classical model of crime, according to which the deterrent effect of a sanction depends on its expected costs (Becker 1968).

useful.

The answer to whether debarments effectively deter collusion is far from obvious. On the one hand, debarments are used as a sanction and should discourage collusive behavior. On the other hand, by reducing the size of procurement markets, debarments may facilitate collusion and higher bids among non-debarred bidders (Tirole 1988; Levenstein and Suslow 2006; Fonseca and Normann 2012).[3] This problem may arise with respect to *explicit collusion*, i.e. any agreement aimed at limiting competition and sharing the surplus from non-competitive bidding (Marshall and Marx 2012), and to *tacit collusion*, i.e. the coordination of bids without explicit communication, side-contracting or transfers (see Ayres 1987; Cramton and Schwartz 2002; Bajari and Yeo 2009; Fonseca and Normann 2012).[4] Irrespective of the specific mode of collusion, debarments may be a double-edged sword, as they may trigger the very behavior they aim to deter.

This article reports evidence from the first experimental study on the impact of debarments on (explicit and tacit) collusion and bidding behavior in procurement auctions. We explore whether debarment deters collusion by comparing it with the benchmark case of no sanction. To explore how the deterrent effect of debarment varies with its length, we vary the length of bidder exclusion. Moreover, we explore whether and how the exclusion of colluding bidders affects the bids of non-debarred bidders. Since fines are the most common alternative to debarments in the practice of procurement authorities, we compare debarments with fines as an extension.[5]

We find that debarments significantly reduce the frequency of collusion relative to the no sanction baseline, and decrease bids towards the competitive level. This deterrent effect increases with the length of the debarment. However, under the short debarment regime, the exclusion of colluding bidders increases the bids of

3. Throughout this article, we consider a closed market, i.e. a market with no entry exposing incumbent bidders to competition.

4. Throughout this article, the terms *explicit collusion* and *bidding rings* are used interchangeably.

5. The World Bank has imposed fines in the Siemens case: the Siemens Group agreed to pay USD 100 million as part of a settlement agreement (Fariello and Bo 2015). Fines have also been levied to sanction collusion in procurement auctions for the supply of school milk in the US (Porter and Zona 1999).

non-debarred bidders. This suggests that the reduced thickness of the auction market generated by the exclusion of colluding bidders may facilitate tacit collusion among bidders who remain in the market. Interestingly, we do not observe this effect under the long debarment. The reason may be the following. The short debarment is less deterrent than the long one, which implies that debarments are more frequent. As a result, in the short debarment non-debarred bidders interact in a smaller market for longer and thus have more time to learn about the additional earning opportunities opened up by the reduced market size. Moreover, short debarments reduce efficiency, because bidder exclusions are more frequent and the bidder with the lowest cost is less likely to win the auction. Finally, we do not find a significant difference between the short debarment and the fine but for one result: the fine yields significantly higher efficiency levels than the short debarment.

To the best of our knowledge, we present the first experimental study on the impact of debarments on collusion in procurement auctions. On the one hand, we extend the small literature on debarment and corruption (Auriol and Søreide 2017) by exploring the effect on debarment on collusion. Coey, Larsen, and Sweeney (2019) investigate the expected revenue drops resulting from a random bidder exclusion, whereas we (experimentally) study the effects of targeted bidder exclusions as a sanction against collusion. On the other hand, we contribute to the literature on collusion (Kaplow 2011; Engel 2015) and, more specifically, to the literature strand on collusion in procurement auctions (Milgrom and Weber 1982; Porter and Zona 1993, 1999; Pesendorfer 2000; Bajari and Ye 2003; Skrzypacz and Hopenhayn 2004; Fugger, Katok, and Wambach 2015; Brosig-Koch, Güth, and Weiland 2016).

Most experimental studies have focused on the impact of the auction format on bid rigging. Hu, Offerman, and Onderstal (2011), for example, show that collusion rates are lower in the Amsterdam second-price auction than in the English auction and the first-price sealed-bid auction. Hinloopen and Onderstal (2014) find that antitrust policies tend to facilitate a breakdown of collusion in the first-price auction, while being largely ineffective in the English auction. In the setup explored by Llorente-Saguer and Zultan (2017), one bidder can bribe the other bidder to stay out of a first-price or second-price private-values auction, but the

authors find no difference in bribing behavior across auction formats. Agranov and Yariv (2018) show that pre-play communication and post-auction side-payments in one-shot first-price and second-price sealed-bid auctions entail a strong reduction of revenues, whereas the auction format has no effect on collusion. Finally, Noussair and Seres (2020) explore a second-price sealed-bid auction with private and common value components, and find that collusion reduces efficiency.

Only a few experimental studies have narrowed down their focus on sanctions and, more specifically, fines (see Bigoni et al. 2012, 2015). Hamaguchi et al. (2007), for example, investigate the effect of fines in a repeated procurement auction. Hinloopen and Onderstal (2014) study the impact of leniency programs in English and first-price sealed-bid auctions and find that leniency programs stabilize cartels and reduce the average winning cartel bid in first-price sealed-bid auctions. However, none of these studies has explored alternative remedies intended to weed out the vulnerability to collusion.

The remainder of our article is organized as follows. Section 2 discusses the legal background. Section 3 presents the theoretical model. We then present our experimental design and testable predictions in Section 4. Section 5 reports the results of the experiment. Section 6 concludes.

2 Legal background

Our study relates to a long-standing legal debate about the purpose and effects of debarments. Some authors have praised the deterrent effects of debarments and advocated their use as criminal sanctions against large corporations (Stevenson and Wagoner 2011). Others have categorized debarments as administrative tools (Tillipman 2012, 2013). On an administrative view, debarments do not serve any punishment purpose, such as deterrence, retribution, or rehabilitation. While these functions are usually attributed to criminal law, debarments are simply intended to provide government authorities the possibility to award contracts in a way that minimizes the strain on public budgets. On that view, it is irrelevant whether debarments actually generate effects that are equivalent to those typically

associated with punishments. Following that spirit, the US Congress enacted the first debarment provision in the Act of July 5, 1884, which required the executive branch to award contracts to the "lowest responsible bidder". Moving towards a more punitive regime, the US legislator established a protectionist debarment regime in the *Buy America Act*, 42 U.S.C. § 10.

However, the US legislator later turned a backward somersault and established Part 9.402(b) of the US Federal Acquisition Regulation providing that debarments are to be imposed "not for purposes of punishment" but "only in the public interest for the Government's protection". A similar administrative debarment regime is enshrined in Art. 57(4)(d) EU Procurement Directive 2014/24/EU.[6] The upshot of both US and EU law is that debarments are not used as sanctioning tools as part of the criminal law system but as administrative remedies to protect the government from imminent harm that irresponsible bidders may cause (Tillipman 2012, 2013).

The World Bank and other international development banks have taken a different approach to debarments (Dubois and Nowlan 2010; Seiler and Madir 2012; Fariello and Daly 2013; Fariello and Bo 2015). Functionally, debarments come much closer to criminal law sanctions (Søreide, Groning, and Wandall 2016), even if they are formally qualified as administrative remedies (Dubois 2012; Leroy and Fariello 2012). Under Section 1.01(b) of the World Bank Sanctions Procedures and the World Bank Sanctioning Guidelines, the sanctions regime explicitly serves as a deterrent upon those who might otherwise engage in a misuse of Bank funds. The practices subject to debarments under the current World Bank sanctions regime not only include corrupt, fraudulent, coercive and obstructive practices but also collusive practices, i.e. acts that attempt "to simulate competition or to establish bid prices at artificial, non-competitive levels, or are privy to each other's bid

6. Accordingly, a contracting authority may exclude from a procurement procedure an economic operator if it "has sufficiently plausible indications to conclude that the economic operator has entered into agreements with other economic operators aimed at distorting competition". §§ 123, 124 of the German Antitrust Act (GWB) transpose the EU Procurement Directive 2014/24/EU, including provisions on statutory and discretionary debarments, into the German legal order.

prices or other conditions" (Section 1.16 of the World Bank Procurement Guidelines, Section 1.02 of the World Bank Sanctions Procedures). Under Section 9.01 of the World Bank Sanctions Procedures and the World Bank Sanctioning Guidelines, the World Bank can impose different types of debarments including debarment, over debarment with conditional release, conditional non-debarment to permanent debarment.

3 Theoretical framework

In this section, we describe the theoretical framework and derive our testable predictions. The theoretical framework closely matches our experimental design. In Subsection 3.1, we present the benchmark game: a finitely repeated first-price sealed-bid procurement auction with the possibility to collude and no sanction. In Subsection 3.2, we introduce debarments as a sanction for collusive behavior.[7]

3.1 Benchmark auction game

3.1.1 Model set-up

In every period $t \leq T$, the game has the following stages.

- **Stage 0.** Nature draws the private costs of $n_s = 2$ strong risk-neutral bidders and $n_w = 2$ weak risk-neutral bidders, denoted by c_{ikt}, where $i \in \{1, 2\}$, $k \in \{s, w\}$ and $n = n_s + n_w$.[8] Costs are private information.

- **Stage 1**. The strong bidders simultaneously decide whether or not to form a bidding ring. A bidding ring is formed if both strong bidders agree to collude. If no bidding ring is formed, the game proceeds to Stage 3.

7. The game is repeated because debarment implies the exclusion of colluding bidders for some periods. In Appendix A, we present a variant of the game with fines.

8. This reflects the fact that in most auctions not all bidders have equal bidding strength. In addition, we need weak bidders who are not allowed to form a bidding ring because otherwise when strong bidders are excluded under the debarment regime there would be no remaining players in the market. We would thus be unable to observe the effect of debarment on the behavior of non-debarred bidders.

- **Stage 2**. If a bidding ring is formed, its members implement a first-price preauction knock-out (PAKT). The ring member submitting the highest bid becomes the designated bidder in the procurement auction and makes a transfer to the other strong bidder.

- **Stage 3**. All the bidders participate in the procurement auction.

PAKT In a first-price auction, the bidder with the lowest cost can affect the price she receives and therefore has an incentive to bid above her cost (Vickrey 1961; Ausubel and Milgrom 2006; Krishna 2010). In our case, this exposes the ring leader to the risk of being undercut by the other ring member.[9] To avoid this, we allow for enforceable side payments in a pre-auction knock-out that is designed to induce bidders to truthfully reveal their private costs (see McAfee and McMillan 1992).[10] In the PAKT, the bid is an offer to make a side payment to the other ring member. The designated bidder represents the ring in the procurement auction and submits both the winning bid and a shill bid for the highest-cost strong bidder, also referred to as the non-designated bidder.

Procurement auction We assume that, as in our experiment, in each period each strong bidder's private cost c_{ist} is independently drawn from a uniform distribution $U(c_{ist})$ with support $[\underline{c}_s, \bar{c}_s]$, and each weak bidder's private cost c_{iwt} is independently drawn from a uniform distribution $U(c_{iwt})$ with support $[\underline{c}_w, \bar{c}_w]$, where $\underline{c}_w > \bar{c}_s$ and $\underline{c}_s > 0$. All bidders know their private costs and the distribution of the other bidders' private costs. Let R denote the bid cap (the buyer's reserve price), where $R > \bar{c}_w$.

If the strong bidders choose not to form a bidding ring in Stage 1 of the game, Stage 3 is a competitive procurement auction. In every period t, each bidder i, of type k, simultaneously submits a sealed bid, $b_{ikt} < R$. The bidder submitting the

9. This illustrates that collusion through bidding rings is not stable in first-price procurement auctions (see Stigler 1964; Marshall and Marx 2007, 2009).

10. PAKTs have been used by various bidding rings over the last 200 years, covering auctions for antique books, stamps, paintings or farm land (see Asker 2010).

lowest bid obtains the contract and receives $b_{ikt} - c_{ikt}$. Each bidder maximizes her profit:

$$\pi_{ikt} = \begin{cases} b_{ikt} - c_{ikt} & \text{if } i \text{ obtains the contract} \\ 0 & \text{otherwise} \end{cases} \tag{1}$$

If the strong bidders choose to collude in Stage 1 of the game, then one strong bidder will be designated as the ring leader, or designated bidder, and the other strong bidder will submit shill bids.

3.1.2 Equilibrium analysis

In what follows, we derive the perfect Bayesian equilibrium. Following related literature, we assume that the two strong bidders use the same strategy. The game is solved by backward induction, starting with the procurement auction in Stage 3.

Procurement auction

Case I: No collusion in Stage 1 The strong bidder's symmetric equilibrium bidding function is:

$$b(c_{ist}) = \frac{\bar{c}_s}{2} + \frac{c_{ist}}{2} \tag{2}$$

The derivation of the bidding function in our setting with $n_s = 2$ and $c_{ist} \sim U[\underline{c}_s, \bar{c}_s]$ and in a more general case can be found in Appendix B.1.

As $\underline{c}_w > \bar{c}_s$ and because the bidding function is monotonically increasing in c_{iwt}, the weak bidders' probability of winning is zero. Therefore, any bid within their cost interval will be an equilibrium for weak bidders.

Case II: Collusion in Stage 1 Suppose that the *lowest-cost strong bidder*, i.e. the strong bidder with the lowest cost, is designated as the ring leader.[11] The equilibrium bid of the ring leader is given by:

11. This is true in equilibrium.

$$b(c_{ist}) = \underline{c}_w \tag{3}$$

As the weak bidders' probability of winning is zero, any bid within their cost interval will be an equilibrium for them.[12]

PAKT If a bidding ring is formed in Stage 1, the PAKT in Stage 2 takes place. The symmetric equilibrium bid in the PAKT, and thus the equilibrium side payment, is given by:

$$\kappa(c_{ist}) = \frac{1}{2}\Big(\underline{c}_w - c_{ist}\Big) \tag{4}$$

The ring leader and the other ring member will earn the same in the PAKT (see Appendix B.1). The equilibrium side payment, i.e. the equilibrium bid in the PAKT, incentivizes the *highest-cost strong bidder*, i.e. the strong bidder with the highest cost, not to mimic the lowest-cost strong bidder, as Claim 1 states.

Claim 1. *The equilibrium side payment*

$$\frac{1}{2}\Big(\underline{c}_w - c_{ist}\Big)$$

is incentive compatible.

Proof. See Appendix B.1.

Collusion decision A strong bidder will collude if the expected payoff from colluding, conditional on the other strong bidder joining the ring, is weakly larger than the expected payoff from not colluding.[13] In the absence of any sanction, in every period of the auction game the expected payoff from colluding will exceed the expected payoff from not colluding for any private costs of the strong bidders. Thus, strong bidders will always collude. Proposition 1 summarizes collusion and bidding behavior in the auction game with no sanction.

12. We assume an efficient tie-breaking rule: if two or more bids are the same, the winning bidder is the one with the lowest cost. This implies that if the ring leader and a weak bidder submit the same bid, the ring leader will win the auction.

13. We assume that, if indifferent, strong bidders collude.

Proposition 1. *In the auction game with no sanction, the strong bidders will collude in every period, for any private costs. The equilibrium bid of the ring leader will be* $b(c_{ist}) = \underline{c}_w$.

Proof. See Appendix B.1.

3.2 Auction game with debarment

3.2.1 Set-up

In $t = T$, the auction game with debarment is the same as the bechmark game, as no punishment can occur. In any period $t < T$, if the strong bidders collude, in $t + 1$ they will be excluded from the auction for one period with a probability of $p = 0.5$.[14] In any $t < T$ (and if nobody is debarred) the auction game includes the following stages.

- **Stage 0 to Stage 3.** As in the benchmark game.
- **Stage 4**. If a bidding ring is formed, it will be detected with a probability of $p = 0.5$. When a bidding ring is detected, its members are debarred from the auction for one period.

When the strong bidders are debarred, only the costs of the weak bidders are drawn in Stage 0 and only weak bidders participate in the procurement auction in Stage 3. Stage 1, Stage 2 and Stage 4 do not take place.

3.2.2 Equilibrium analysis

The equilibrium bidding behavior in the procurement auction and in the PAKT are the same as in the benchmark game. However, the collusion decision is affected.

14. We consider a one-period exclusion for simplicity. The results derived for one-period debarment hold for longer debarments. In the experiment, we explore a 3-period debarment and a 6-period debarment.

Collusion decision In the last period, behavior under debarment is the same as behavior under no sanction, as no punishment can occur. In all the previous periods, the expected cost of colluding under debarment is positive, whereas the expected cost of colluding under no sanction is zero.

Proposition 2. *Under debarment, in $t = T$ the strong bidders will collude for any private cost, as under no sanction. In any $t < T$, the strong bidders will be less likely to collude under debarment than under no sanction. As a result, equilibrium bids will be lower under debarment than under no sanction.*

Proof. See Appendix B.2.

As the number of periods that colluding bidders are excluded for increases, the expected payoff from not colluding increases, and consequently the probability of collusion decreases.

Corollary 1. *The probability of collusion decreases as the length of the debarment increases.*

Proof. See Appendix B.2.

Weak bidders. As discussed, in case of collusion and in the absence of any sanction, any bid within the weak bidders' cost interval and lower than the bid cap R will be an equilibrium. However, under debarment weak bidders know that, when the strong bidders are excluded, they are (alone) in a competitive auction and have a chance to win. Hence their equilibrium bid will be:[15]

$$b(c_{iwt}) = \frac{\bar{c}_w}{2} + \frac{c_{iwt}}{2}$$

15. Weak bidders may also bid beyond the competitive equilibrium bid, if they try to tacitly collude.

4 Experimental design

Our experiment proceeded in three parts (Figure 1).[16] Part 1 and Part 2 were common to all treatments. Part 1 consisted of 8 rounds of a procurement auction with no opportunity to form bidding rings. Part 2 consisted of 8 rounds of a procurement auction with the opportunity to form bidding rings. Part 3 consisted of 16 rounds of a procurement auction with the opportunity to form bidding rings and our between-subjects sanctions treatment. Following related studies (see Hu, Offerman, and Onderstal 2011), we deliberately increased complexity over these three parts to facilitate subjects' understanding of the game. In particular, Part 1 and Part 2 were designed to let subjects experience respectively a competitive environment and a collusive environment before interacting in the more complex environment with both collusion and sanctions (our treatments) in Part 3.

Subjects were randomly assigned to groups of four at the beginning of the experiment. Each group consisted of two strong bidders and two weak bidders. Groups were fixed in each part, as debarment requires fixed groups.[17] Because groups had to be fixed in the debarment treatment in Part 3, they also had to be in the other treatments and in the other parts. Moreover, fixed groups facilitate learning.

In Part 1 and Part 2, each subject was randomly assigned the role of strong or weak bidder at the beginning of each round. Reassigning the roles in each round ensured that subjects did not always play either in the role of weak bidder or in the role of strong bidder. The latter, in fact, would lead to (i) a very unequal income distribution in the experiment, (ii) different learning experiences for always-weak and always-strong bidders (most notably, always-weak bidders would never experience collusion before reaching Part 3), and (iii) always-weak bidders feeling

16. At the beginning of the experiment, subjects knew they would participate in three parts but they received instructions for the next part only after the end of the previous part.

17. First, if we had debarred colluding bidders and then re-matched subjects into new groups, we would not have been able to observe the effect of debarment on the remaining bidders. Second, due to the exclusion of some strong bidders under debarment, re-matching subjects in each round would not have guaranteed that groups of weak and strong bidders would always be formed.

that they have been treated unfairly and thus playing resentfully.

At the beginning of Part 3, each subject was randomly re-matched with three subjects she had not previously interacted with (perfect strangers re-matching).[18] Each subject was then assigned the role of strong or weak bidder, and kept this role for all 16 rounds of Part 3. Thus, each group is one independent observation. As we had 48 participants per treatment, this gives us 12 independent observations per treatment.

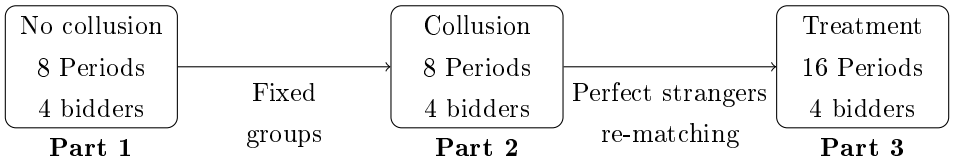

Figure 1: Timeline of the experiment

4.1 Basic game

At the beginning of each round, each strong bidder was randomly assigned an individual cost from the distribution $U[20, 60]$, whereas each weak bidder was randomly assigned an individual cost from $U[80, 120]$. Costs were private information.[19] The strong bidders then individually and simultaneously decided whether they wanted to form a bidding ring – neutrally referred to as an "agreement".[20] A bidding ring was only formed if both the strong bidders opted for this option. Weak bidders did not learn whether a bidding ring had been formed.

If a bidding ring was not formed, all bidders proceeded to the procurement auction and placed their bids. If a bidding ring was formed, each strong bidder

18. We did not additionally re-match subjects at the beginning of Part 2 in order to (i) avoid dependence between parts and (ii) keep the game as simple as possible for subjects. An additional re-matching would have overwhelmed subjects and distracted their attention from the task at hand.

19. In Part 3, we elicited the bidders' beliefs about the other bidders' costs, regardless of whether a ring was formed.

20. As mentioned above, strong bidders did not have this opportunity in Part 1.

simultaneously stated the side payment they would transfer to the other strong bidder if they became the designated bidder. The strong bidder stating the higher amount became the designated bidder. Side payments were enforced. Note that in weak bidding rings, such as those involving bid rotation schemes, side payments cannot be enforced. In order to avoid potential confounds, such as trust and cheating, we built on existing evidence of strong bidding rings (McAfee and McMillan 1992; Asker 2010) and designed our experiment to allow for a PAKT (see Hu, Offerman, and Onderstal 2011; Noussair and Seres 2020). After the PAKT, the weak bidders and the designated bidder proceeded to the procurement auction. The designated bidder submitted her own bid and a shill bid for the non-designated bidder.

In the procurement auction, all bidders could submit bids up to the bid cap $R = 140$.[21] Tied bids were randomly broken. The bidder submitting the lowest bid won the auction and earned an amount equal to her bid. The other bidders did not earn anything. After the auction, each bidder learned whether she had won the auction and the others' bids. At the end of each round, we elicited bidders' beliefs about the other bidders' costs. The main purpose of this belief elicitation was to assess weak bidders' responses to debarment and their belief about potential bid inflation by the other weak bidder.

4.2 Treatments

The four treatments we ran in Part 3 are summarized in Table 1. The baseline treatment without a sanction (*No sanction*) consisted of 16 rounds of the basic game described in the previous section. In the 6-period debarment (*DebarLong*) and the 3-period debarment (*DebarShort*), bidding rings were detected with a

21. Note that lowering the bid cap can be used as a means of reducing the incentives for collusion. An effective use of this tool, however, requires information about the distribution of costs that procurement authorities usually do not have. Our design accounts for this information problem and reflects the intuition that procurement authorities have an interest in attracting enough bidders and securing thick markets by adopting a bid cap that is sufficiently high.

probability of $p = 0.5$.[22] In case of detection, both strong bidders were unable to bid in the auction for the 6 rounds or 3 rounds, respectively, following detection. Strong bidders could only be excluded together (never singly) and only for a ring formed in the current round (never for a ring formed in a previous round). Beliefs were always elicited, regardless of whether strong bidders were debarred, in order to prevent the risk of additional and undesired differences across treatments. Weak bidders participated in the auction as normal when strong bidders were debarred, and were informed about their debarment.[23] This enables us to investigate whether debarment fosters tacit collusion among non-debarred bidders. Finally, we ran a treatment with fines (*Fine*), where bidding rings were detected with a probability of $p = 0.5$. In the event of detection, the fine was subtracted from the strong bidders' earnings up to that round (including the earnings in the current round). The amount of the fine was calibrated so as to be equivalent to the expected cost of being debarred for 3 rounds. As strong bidders forewent on average 8 points per round in the debarred rounds of *DebarShort*, the fine was set to 24 points.

Table 1: Treatments

Treatment	Severity	Probability
No sanction		
DebarLong	6 rounds	0.5
DebarShort	3 rounds	0.5
Fine	24 Points	0.5

4.3 Procedure

The experiment was programmed using the experimental software *z-Tree* (Fischbacher 2007) and conducted at the BonnEconLab of the University of Bonn,

22. While the probability of detection might depend on the severity of the sanction in practice, we assume an exogenous and constant probability of detection and only manipulate the severity of the sanction.

23. Weak bidders, however, did not learn whether collusion had occurred.

with a total of 236 subjects. Subjects were recruited via *hroot* (Bock, Baetge, and Nicklisch 2014) and participated in 8 sessions and 2 pilot sessions. The pilot sessions were used to calibrate the experiment. In this article, we only report the results from our 8 sessions (2 sessions per treatment), with a total of 196 subjects (48 subjects per treatment). Before each part of the experiment, subjects had to answer control questions in order to proceed to the actual experiment. In each treatment, we measured risk preferences (Holt and Laury 2002), the impact of the number of competitors on competitiveness (Garcia and Tor 2009; Garcia, Tor, and Schiff 2013),[24] and demographic characteristics. At the end of the experiment, subjects received the sum of their earnings in Part 1 and Part 2 or their earnings in Part 3, in addition to a show-up fee of 6 Euros. On average, subjects earned 17.04 Euros.

4.4 Hypotheses

In this subsection, we derive testable predictions from our theoretical results in Section 3. In the absence of sanctions, strong bidders will collude in each period for any private costs (Proposition 1). Under debarments (Proposition 2) and under fines (Proposition 3), strong bidders are less likely to collude than in the absence of any sanction, and consequently bids are lower. The probability of collusion decreases as the length of debarment increases (Corollary 1). This leads to the following hypotheses.

Hypothesis 1.
Strong bidders are less likely to collude under debarments and fines than in the absence of any sanction.

Hypothesis 2.
Strong bidders are less likely to collude under the long debarment than under the short debarment.

24. To control for ratio bias, we used the survey questions proposed by Denes-Raj and Epstein (1994). See Appendix C.3.

Under sanctions, there will be less periods with non-competitive bidding. Therefore, strong bidders' bids will be lower under sanctions than without sanctions.

Hypothesis 3.
Strong bidders' bids are lower under debarments and fines than in the absence of any sanction.

5 Results

5.1 Summary

Table 2 presents the percentage of collusion and the bids submitted by strong bidders in all parts of the experiment. In Part 3, mean collusion is higher in the absence of a sanction than under debarments and fines, and decreases with the length of the debarment (see Figure 2). Similarly, mean bids are higher with no sanction than with debarments or fines, and decrease with the length of the debarment (see Figure 3).

Bids are markedly higher in Part 2, where collusion was possible, than in Part 1, where collusion was not possible. Moreover, we observe only small differences in collusion levels across treatments in Part 2. We also observe small differences in bids across treatments, in Part 1 and Part 2. Part 3, however, features very strong variations of collusion levels and bids across treatments. This indicates that our randomization procedure worked.

Table 2: Summary statistics for strong bidders

	Part 1		Part 2		Part 3	
	Collusion	Bids	Collusion	Bids	Collusion	Bids
No sanction	–	49.688	0.849	74.635	0.917	81.870
DebarLong	–	47.099	0.807	72.120	0.226	49.092
DebarShort	–	48.984	0.865	72.818	0.575	59.975
Fine	–	46.677	0.922	79.010	0.484	58.469
N	192	192	192	192	384	384

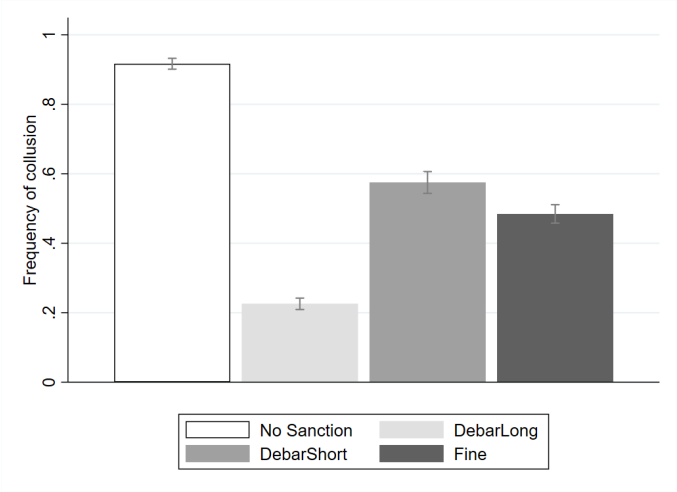

Figure 2: Mean frequency of collusion by treatment.

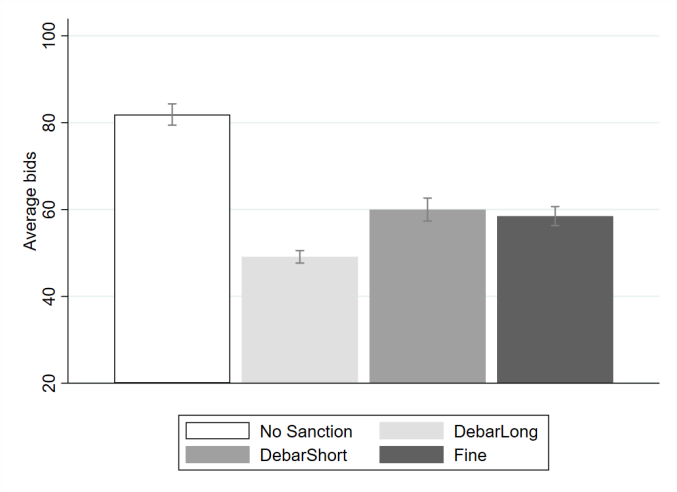

Figure 3: Mean strong bidders' bids by treatment.

5.2 Methodology

We estimate OLS and logit regressions with standard errors clustered at the group level. In addition, to account for intrasubject and intragroup dependence over time, we estimate a three-level random effects model (for a similar approach, see Hu, Offerman, and Onderstal 2011; Bigoni et al. 2012, 2015) and present the results in

Appendix C.1. The second level of clustering accounts for the dependence of each subject's observations over the 16 rounds. The third level of clustering accounts for the dependence of each group over the 16 rounds in Part 3. We do not cluster at higher levels to account for Part-specific, session-specific or time-specific random effects. Given that behavior in Part 1 and Part 2 is relatively constant across treatments and given the perfect strangers re-matching before Part 3, we do not deem it necessary to consider dependence at these levels.

As a robustness check, we run parametric and non-parametric tests (t-test and Mann-Whitney test) at the group observation level. Finally, we use the Wald test to assess differences across treatments. Specifically, we hypothesize that the coefficients of our treatment dummies are equal to each other.

5.3 Effect of debarment and fines

5.3.1 Collusion

Following the literature (Hinloopen and Soetevent 2008; Bigoni et al. 2015; Chowdhury and Wandschneider 2018), collusion is a dummy variable taking value 1 when a strong bidder agrees to form a bidding ring, and 0 otherwise. While collusion rates are as high as 91.7 % in the no sanction baseline, they drop to to 22.6 % in the long debarment treatment, to 57.5 % in the short debarment treatment and to 48.8 % in the fines treatment.[25] This drop in collusion rates generated by each of the three sanctions in comparison to the no sanction baseline is highly significant (t-test and Mann-Whitney, $p < 0.01$). Table 3 presents the marginal effects of the three sanctions on collusion, relative to the no sanction baseline, using a logit model with standard errors clustered at the group level. In column (1) we only control for the treatment dummies, in column (2) we also control for private cost and risk aversion, and in column (3) we also control for demographic character-

25. An alternative measure of collusion might consider the frequency of *bidding rings* rather than *individual collusion propensities*. Using this measure, the treatment effects become even larger. While bidding rings form in 83.3 % of rounds in the no sanction baseline, they form in only 4.4 % of rounds under the long debarment, in 40.6 % of rounds under the short debarment, and in 26 % of rounds under the fine.

istics (gender and age).[26] Confirming the results of the non-parametric tests, all our specifications show that the short debarment, the long debarment and the fine significantly reduce the frequency of collusion. This strongly supports Hypothesis 1.

Result 1. The frequency of collusion is significantly lower under debarments and under fines than in the absence of any sanction.

When comparing the short and the long debarment, we find that strong bidders were debarred much more frequently under the short debarment (in only 27.08 % of all rounds) than under the long debarment (in 6.77 % of all rounds). This difference can be explained by the fact that long debarment is more deterrent than short debarment, which supports Hypothesis 2.

Result 2. The frequency of collusion is significantly lower under the long debarment than under the short debarment.

When comparing the short debarment and the fine, we find no difference in the frequency of collusion (for a further comparison of the short debarment and the fine, see Subsection 5.4). Exploring the impact of risk preferences, we find that risk aversion explains a decrease in collusion. This indicates that more risk-averse subjects are more concerned about potential sanctions. Using a three-level random effects model (see Table 10 in Appendix C), we obtain the same results.

5.3.2 Bids

Consistent with our results on the effect of the sanctions on collusion, we find that strong bidders' bids are significantly lower under debarments and fines than in the no sanction baseline (t-test and Mann-Whitney, $p < 0.01$).[27] Table 4 presents the effect of the sanctions on bids using a linear regression model with standard errors clustered at the group level. Both debarments and fines significantly decrease

26. Controlling for round effects in order to account for experience does not change any of the results.

27. We only consider non-debarred rounds to avoid a downward bias in our estimates.

Table 3: Impact of sanctions on collusion

DV: Collusion	(1)	(2)	(3)
Baseline: No sanction			
DebarLong	-0.707***	-0.688***	-0.680***
	(0.063)	(0.065)	(0.064)
DebarShort	-0.445***	-0.445***	-0.428***
	(0.096)	(0.092)	(0.097)
Fine	-0.432***	-0.451***	-0.444***
	(0.090)	(0.085)	(0.082)
Cost		0.003	0.003*
		(0.002)	(0.002)
Risk aversion		-0.105*	-0.099*
		(0.057)	(0.054)
Demographics	no	no	yes
Wald test	12.96***	11.18***	11.76***
N	1406	1406	1406

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$

Logit regression. Standard errors in parentheses, clustered at group level. All coefficients are reported as average marginal effects.

bids, which supports Hypothesis 3.[28] In addition, we find that the long debarment decreases bids more than the short debarment – an effect that corroborates our previous result.

Result 3. Strong bidders' bids are lower under debarments and under fines than in the absence of any sanction.

The decrease in bids generated by the fine is stronger than that generated by the short debarment, which suggests a behavioral effect (for a detailed comparison, see Subsection 5.4). Apart from that, bidding behavior follows the patterns of standard theory. While higher costs lead to higher bids, risk aversion explains a decrease in bids. The latter is in line with our results on collusion. More risk-averse subjects bid less, because they collude less and are thus more concerned about winning the auction in a competitive manner. Using a three-level random effects model (see Table 11 in Appendix C.1), we obtain the same results. Finally, we observe stable bidding patterns over all rounds across all treatments (see Table 5 in Appendix C.2). This suggests that none of the sanctions triggers any specific dynamics in the procurement auction game.

Our analysis also indicates that colluding bidders are not just risk seekers with respect to the risk of being sanctioned. Figure 4 shows that some strong bidders actually submit bids above the weak bidders' lower cost bound, thereby incurring the risk of losing the auction, especially in the no sanction baseline. Moreover, while we do not find any evidence of underbidding or of the winner's curse, strong bidders have a tendency to submit bids that are relatively close to their costs under the long debarment. This indicates that strong bidders – explicit collusion being too risky – do not exploit the opportunity of tacit collusion by submitting higher bids. Strong bidders may have interpreted debarment as a clear signal that orchestrated behavior and supracompetitive bids are considered as morally or legally wrongful.

28. While discouraging explicit collusion (i.e. the formation of bidding rings), sanctions could potentially induce strong bidders to tacitly collude. We find no evidence of such an effect.

Table 4: Impact of sanctions on strong bidders' bids

DV: Bids	(1)	(2)	(3)
Baseline: No sanction			
DebarLong	-32.442***	-31.188***	-30.496***
	(4.652)	(4.689)	(4.430)
DebarShort	-17.439***	-17.442***	-16.676***
	(6.511)	(6.301)	(5.911)
Fine	-23.401***	-23.853***	-23.258***
	(6.279)	(6.228)	(5.809)
Cost		0.617***	0.617***
		(0.058)	(0.058)
Risk aversion		-4.984*	-4.714*
		(2.801)	(2.600)
Demographics	no	no	yes
Wald test	13.34***	11.85***	11.91***
N	1406	1406	1406

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$

OLS. Standard errors in parentheses, clustered at group level.

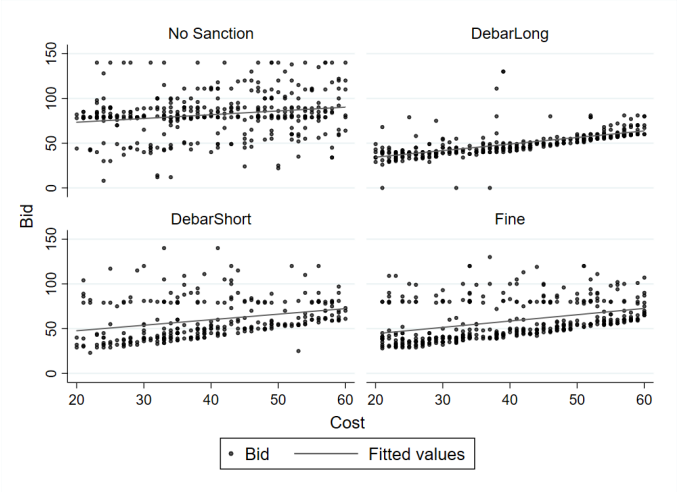

Figure 4: Strong bidders' bids as a function of the costs.

5.4 Comparison between debarment and fines

Fines are the most common alternative to debarments. In this Subsection, as an extension, we compare the effect of the short debarment on collusion and strong bidders' bids with that of fines. Of course, the two sanctions operate in different ways. In order to make the comparison as accurate as possible, we calibrated the fine so as to make the expected cost of being fined equivalent to the expected cost of being debarred for three periods.

In the presence of behavioral effects, specifically loss aversion (see Kahneman and Tversky 1979), the two sanctions could have a different effect on collusion and bids. While strong bidders may forego future and uncertain earnings in the debarment regime, they may lose earnings they have already made in the fines regime. If losing money already earned looms larger than foregoing potential future earnings, collusion should be less frequent in the fines regime than in the short debarment regime. In the absence of any behavioral effect, the impact of these two sanctions on collusion and bids should be the same.

We find some evidence in support of such a behavioral effect. While strong bidders collude in 57.5 % of rounds under the short debarment, they collude significantly less (in 48.4 % of rounds) under the fines (t-test and Mann-Whitney,

$p < 0.01$). The decrease of collusion generated by the short debarment in comparison to the fine becomes even more pronounced when considering bidding rings rather than individual collusion propensities (40.6 % under the short debarment, 26 % under the fine). This result, however, is not robust to a parametric analysis. Table 5 presents the effect of the short debarment on collusion (left-hand side of each column) and on bids (right-hand side of each column), as compared to the fine. The decrease in collusion and bids generated by the short debarment is not significantly different from that generated by the fine.

Table 5: Effect of short debarment relative to fines

	(1)		(2)		(3)	
DV	Collusion	Bids	Collusion	Bids	Collusion	Bids
Baseline: Fine						
DebarShort	-0.013	5.962	0.006	6.411	0.016	6.582
	(0.115)	(6.377)	(0.107)	(5.910)	(0.107)	(5.534)
Cost	no		yes		yes	
Risk aversion	no		yes		yes	
Demographics	no		no		yes	
N	1406		1406		1406	

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$

LHS: Logit regression. Coefficients are reported as average marginal effects. RHS: OLS. Standard errors in parentheses, clustered at group level.

5.5 Weak bidders

Our experiment was also designed to investigate the impact of the sanctions on weak bidders' bids. An observed increase of weak bidders' bids could be interpreted as evidence of tacit collusion, i.e. as the result of implied coordination on bids among weak bidders due to reduced competitive pressure from strong bidders. When including both debarred and non-debarred rounds (respectively, the rounds in which colluding strong bidders were excluded and the rounds in which they were not), none of the sanctions has an effect on weak bidders' bids (Table 6,

left-hand side of each column). When including debarred rounds only, we observe significantly higher bids under the short debarment than in the no sanction baseline (Table 6, right-hand side of each column). However, the long debarment has no significant impact on bids.[29] Finally, weak bidders' bids do not increase under the fine either.

Result 4. Weak bidders' bids are higher under the short debarment than in the absence of any sanction.

Our data suggest that this difference may be driven by the fact that the long debarment was more deterrent than the short debarment. As a consequence, debarment was more frequent under the short debarment regime than under the long debarment regime. As a result, the strong bidders' probability of winning the auction was much lower under the short debarment (68.23 %) than in the other treatments (no sanction baseline: 86.46 %, long debarment: 86.98 %, fine: 92.71 %). More specifically, strong bidders were debarred in only 6.77 % of all rounds under the long debarment regime and in 27.08 % of all rounds under the short debarment regime. This implies that weak bidders were not exposed to strong bidders' competition for a much longer time under the short debarment regime. Therefore, the short debarment gave weak bidders more opportunities to figure out how to make additional earnings. In other words, weak bidders' bids are higher under the short debarment because its deterrent effect on *strong bidders* is weaker than that of the long debarment.

5.6 Earnings

Strong bidders. As strong bidders did not earn anything when being debarred, we only consider earnings in non-debarred rounds. Consistent with the effect of the sanctions on collusion and bids, mean earnings were lower in each of the sanctions regimes (DebarLong: 4.260, DebarShort: 5.145; Fine: 4.430) than in

29. In line with this result, we observe that the gap between a weak bidder's bid and his belief on the other weak bidder's cost is higher under the short debarment than under no sanction, but it is not higher under the long debarment than under no sanction.

Table 6: Impact of sanctions on weak bidders' bids

	(1)		(2)		(3)	
DV: Bids	All	Debarred	All	Debarred	All	Debarred
Baseline: No sanction						
DebarLong	-4.690	-10.422	-3.044	-6.994	-3.245	-7.993
	(5.168)	(9.862)	(5.107)	(7.541)	(5.164)	(6.754)
DebarShort	2.224	3.136*	3.830	5.306***	4.059	4.863***
	(2.642)	(1.879)	(2.575)	(1.626)	(2.549)	(1.648)
Fine	1.086	1.086	2.243	2.320	1.792	2.176
	(2.789)	(2.803)	(2.570)	(2.471)	(2.574)	(2.336)
Cost			0.832***	0.905***	0.831***	0.906***
			(0.046)	(0.043)	(0.046)	(0.043)
Risk aversion			-1.804	-1.792	-2.027	-2.600
			(3.771)	(3.007)	(3.883)	(2.604)
Demographics	no	no	no	no	yes	yes
Wald test	1.65	2.45	1.56	4.34	2.09	5.16*
N	1536	898	1536	898	1536	898

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$

OLS. Standard errors in parentheses, clustered at group level. LHS: All rounds. RHS: Debarred rounds only.

the baseline (15.643), the difference being highly significant (t-test and Mann-Whitney test, $p < 0.01$). Note that the fine has a stronger effect on the strong bidders' earnings than the short debarment and generates almost the same effect as the long debarment. Table 7 shows that all the sanctions significantly decrease earnings. This result is in line with the fact that strong bidders earned significantly more when a bidding ring was formed than when it was not formed (t-test and Mann-Whitney test, $p < 0.01$).

Table 7: Impact of sanctions on strong bidders' earnings

DV: Earnings	(1)	(2)	(3)
Baseline: No sanction			
DebarLong	-11.262***	-10.837***	-10.711***
	(2.184)	(2.278)	(2.038)
DebarShort	-6.425**	-6.407**	-6.080**
	(2.819)	(2.803)	(2.609)
Fine	-11.214***	-11.508***	-11.346***
	(2.248)	(2.200)	(1.985)
Cost		-0.336***	-0.335***
		(0.029)	(0.029)
Risk aversion		-2.058	-1.938
		(1.431)	(1.281)
Demographics	no	no	yes
Wald test	6.49**	6.60**	7.46**
N	1406	1406	1406

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$

OLS. Standard errors in parentheses, clustered at group level.

Weak bidders. Consistent with our results on bids and tacit collusion, we find no effect of the sanctions on weak bidders' earnings when including all rounds (Table 8, left-hand side of each column). However, when considering debarred rounds only, the short debarment significantly increased weak bidders' earnings relative to the no sanction baseline (Table 8, right-hand side of each column).

Result 5. Both debarments and fines entail a strong reduction of strong bidder earnings, whereas the short debarment increases weak bidder earnings.

Table 8: Impact of sanctions on weak bidders' earnings

	(1)		(2)		(3)	
DV: Earnings	All	Debarred	All	Debarred	All	Debarred
Baseline: No sanction						
DebarLong	-2.122	-2.939	-2.140	-3.051	-2.291	-3.481
	(3.312)	(5.227)	(3.233)	(5.119)	(3.248)	(4.571)
DebarShort	1.115	5.138***	1.315	5.142***	1.221	4.837***
	(1.509)	(1.195)	(1.668)	(1.123)	(1.418)	(0.994)
Fine	-0.094	-0.094	0.187	-0.019	-0.114	0.014
	(1.561)	(1.569)	(1.539)	(1.350)	(1.471)	(1.260)
Cost			-0.061*	-0.051***	-0.061*	-0.051***
			(0.032)	(0.018)	(0.032)	(0.018)
Risk aversion			-2.355	-0.886	-2.673	-1.258
			(2.981)	(1.996)	(3.031)	(1.884)
Demographics	no	no	no	no	yes	yes
Wald test	1.34	21.48***	1.29	23.97***	2.60	20.41***
N	1536	898	1536	898	1536	898

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$

OLS. Standard errors in parentheses, clustered at group level. LHS: All rounds. RHS: Debarred rounds only.

5.7 Efficiency

We define efficiency as the ratio $e = \frac{c_{max} - c_{winner}}{c_{max} - c_{min}}$, i.e. as a continuous variable that takes value 1 when the lowest-cost strong bidder wins the auction, and lower values when other bidders win (for an equivalent measure, see Hu, Offerman, and Onderstal 2011). Table 9 shows that the short debarment significantly reduces efficiency relative to the benchmark with no sanction, whereas the fine and the long debarment have no impact on efficiency. The efficiency ratio is 71.9 % under the short debarment, 87.2 % under the long debarment, 92.3 % under fines, and

87.7 % with no sanction.[30] These efficiency losses imply that the short debarment comes at a high cost for procurement authorities. Accordingly, the average price paid was significantly higher under the short debarment (65.031) than under the long debarment (43.739) and under the fine (50.880) (t-test and Mann-Whitney test, $p < 0.01$). In comparison to the no sanction baseline (70.719), the short debarment entails a relatively small price drop.

Table 9: Impact of sanctions on efficiency

DV: Efficiency	(1)	(2)	(3)
Baseline: No sanction			
DebarLong	-0.004	-0.009	-0.002
	(0.087)	(0.087)	(0.089)
DebarShort	-0.158**	-0.158**	-0.156**
	(0.070)	(0.069)	(0.069)
Fine	0.047	0.049	0.053
	(0.047)	(0.048)	(0.048)
Cost		-0.001	-0.001
		(0.001)	(0.001)
Risk aversion		0.019	0.019
		(0.029)	(0.029)
Demographics	no	no	yes
Wald test	9.81***	10.32***	11.08***
N	1536	153	1536

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$

OLS. Standard errors in parentheses, clustered at group level.

Result 6. The short debarment has a strong and negative effect on efficiency.

This result can be explained by the fact that the short debarment is less deterrent and thus more frequent than the long debarment. This decreases the prob-

30. These are conservative estimates. An alternative efficiency measure e_a might consider separate efficiency ratios for non-debarred and debarred rounds (e_n and e_d) and the respective frequencies of these rounds (f_n and f_d): $e_a = e_n \cdot f_n + e_d \cdot f_d$. Using this measure, the efficiency losses would be even larger.

ability of the lowest-cost strong bidder winning the auction, which drives down efficiency. Debarments of moderate length may hamper efficiency, as they increase the frequency of small markets with high-cost bidders only. If public authorities are concerned with efficiency, they should opt for either *laissez faire* or a sufficiently long and deterrent debarment regime.

6 Conclusion

Despite the widespread use of debarments to deter collusion in procurement auctions, the effect of debarments on collusion has not been (experimentally) investigated in the past. This article fills this gap and presents the results of the first experiment that explores the impact of debarments on collusion in procurement auctions. We compare debarments with a baseline of no sanction and we investigate how the deterrent effect of debarments varies with their length.

We find that debarments strongly decrease collusion and bids, and that these effects increase with the length of the exclusion. However, short debarments increase the bids of non-debarred bidders. This suggests that debarments may trigger tacit collusion among the bidders who remain in the market. Interestingly, this effect is not observed in the long debarment regime. The reason may be the following. As the long debarment regime is much more deterrent than the short one, weak bidders interact in a smaller market for a longer time in the short debarment regime than in the long one. As a result, in the short debarment regime they have more time to learn how to exploit the absence of strong bidders and of the competitive pressure they exert. Finally, short debarments reduce efficiency, because the bidder with the lowest cost is less likely to win the auction.

Our results have important implications for law and public policy. Public authorities that rely on debarments to fight collusion may rest reassured: debarments can be used as an effective deterrent. However, they should be aware that debarments may have undesirable effects if applied with too much leniency. If debarments are not sufficiently deterrent, they will occur too often. As long as incumbent bidders do not face the threat of entry, this will facilitate tacit collusion

among non-debarred bidders and reduce efficiency, as contracts will be awarded to bidders with higher costs. Lawmakers and governments concerned with collusion and the efficient allocation of public funds should opt either for debarments that are sufficiently deterrent or for fines. Debarments that are too lenient may facilitate the very behavior they aim to curb.

References

Agranov, Marina, and Leeat Yariv. 2018. "Collusion through communication in auctions." *Games and Economic Behavior* 107:93–108.

Asker, John. 2010. "A Study of the Internal Organization of a Bidding Cartel." *American Economic Review* 100 (3): 724–62.

Auriol, Emmanuelle, and Tina Søreide. 2017. "An economic analysis of debarment." *International Review of Law and Economics* 50:36–49.

Ausubel, Lawrence M., and Paul Milgrom. 2006. *The Lovely but Lonely Vickrey Auction. In P. Cramton and Y. Shoham and R. Steinberg (Eds.), Combinatorial Auctions. Chapter 1, 22–26.*

Ayres, Ian. 1987. "How Cartels Punish: A Structural Theory of Self-Enforcing Collusion." *Columbia Law Review* 87 (2): 295–325.

Bajari, Patrick, and Lixin Ye. 2003. "Deciding Between Competition and Collusion." *Review of Economics and Statistics* 85 (4): 971–989.

Bajari, Patrick, and Jungwon Yeo. 2009. "Auction Design and Tacit Collusion in FCC Spectrum Auctions." *Information Economics and Policy* 21 (2): 90–100.

Becker, Gary S. 1968. "Crime and Punishment: An Economic Approach." *Journal of Political Economy* 76 (2): 169–217.

Bigoni, Maria, Sven-Olof Fridolfsson, Chloé Le Coq, and Giancarlo Spagnolo. 2012. "Fines, Leniency, and Rewards in antitrust." *RAND Journal of Economics* 43:368–390.

———. 2015. "Trust, Leniency, and Deterrence." *Journal of Law, Economics, and Organization* 31:663–689.

Bock, Olaf, Ingmar Baetge, and Andreas Nicklisch. 2014. "hroot: Hamburg registration and organization online tool." *European Economic Review* 71:117–120.

Brosig-Koch, Jeannette, Werner Güth, and Torsten Weiland. 2016. "Comparing the effectiveness of collusion devices in first-price procurement: an auction experiment." *Evolutionary and Institutional Economics Review* 13 (2): 269–295.

Chowdhury, Subhasish M., and Frederick Wandschneider. 2018. "Antitrust and the 'Beckerian Proposition': the Effects of Investigation and Fines on Cartels." In *Handbook of Behavioral Industrial Organization,* edited by Victor Tremblay, Elizabeth Schroeder, and Carol Tremblay, 368–403. Edward Elgar Publishing Ltd.

Coey, Dominic, Bradley Larsen, and Kane Sweeney. 2019. "The bidder exclusion effect." *RAND Journal of Economics* 50 (1): 93–120.

Cramton, Peter, and Jesse A. Schwartz. 2002. "Collusive Bidding in the FCC Spectrum Auctions." *Contributions in Economic Analysis & Policy* 1 (1): 1–18.

Denes-Raj, Veronika, and Seymour Epstein. 1994. "Conflict Between Intuitive and Rational Processing: When People Behave Against Their Better Judgment." *Journal of Personality and Social Psychology* 66 (5): 819–829.

Dubois, Pascale Hélène. 2012. "Domestic and International Administrative Tools to Combat Fraud & Corruption: A Comparison of US Suspension and Debarment with the World Bank's Sanctions System." *University of Chicago Legal Forum:* 195–235.

Dubois, Pascale Hélène, and Aileen Elizabeth Nowlan. 2010. "Global Administrative Law and the Legitimacy of Sanctions Regimes in International Law." *Yale Journal of International Law* 36:15–25.

Engel, Christoph. 2015. "Tacit Collusion: The Neglected Experimental Evidence." *Journal of Empirical Legal Studies* 12:535–577.

Fariello, Frank A., and Giovanni Bo. 2015. "Development-Oriented Alternatives to Debarment as an Anticorruption Accountability Tool." In *The World Bank Legal Review Volume 6 Improving Delivery in Development: The Role of Voice, Social Contract, and Accountability,* 415–435.

Fariello, Frank A., and Conrad C. Daly. 2013. "Coordinating the Fight against Corruption among MDBs: The Past, Present, and Future of Sanctions." *George Washington International Law Review* 45:253–268.

Fischbacher, Urs. 2007. "z-Tree: Zurich toolbox for ready-made economic experiments." *Experimental Economics* 10:171–178.

Fonseca, Miguel A., and Hans-Theo Normann. 2012. "Explicit vs. tacit collusion: The impact of communication in oligopoly experiments." *European Economic Review* 56:1759–1772.

Fugger, Nicolas, Elena Katok, and Achim Wambach. 2015. "Collusion in Dynamic Buyer-Determined Reverse Auctions." *Management Science* 62 (2): 518–533.

Garcia, Stephen M., and Avishalom Tor. 2009. "The N-Effect." *Psychological Science* 20:871–877.

Garcia, Stephen M., Avishalom Tor, and Tyrone M. Schiff. 2013. "The Psychology of Competition." *Perspectives on Psychological Science* 8:634–650.

Hamaguchi, Yasuyo, Toshiko Ishikawa, Masayuki Ishimoto, Yuji Kimura, and Tadanobu Tanno. 2007. *An Experimental Study of Procurement Auctions with Leniency Programs.* Technical report. Competition Policy Research Center Discussion Paper, Atomi University.

Hinloopen, Jeroen, and Sander Onderstal. 2014. "Going once, going twice, reported! Cartel activity and the effectiveness of antitrust policies in experimental auctions." *European Economic Review* 70:317–336.

Hinloopen, Jeroen, and Adriaan R. Soetevent. 2008. "Laboratory evidence on the effectiveness of corporate leniency programs." *RAND Journal of Economics* 39 (2): 607–616.

Holt, Charles A., and Susan K. Laury. 2002. "Risk Aversion and Incentive Effects." *American Economic Review* 92:1644–1655.

Hu, Audrey, Theo Offerman, and Sander Onderstal. 2011. "Fighting collusion in auctions: An experimental investigation." *International Journal of Industrial Organization* 29:84–96.

Kahneman, Daniel, and Amos Tversky. 1979. "Prospect Theory: An Analysis of Decision under Risk." *Econometrica* 47 (2): 263–291.

Kaplow, Louis. 2011. "Direct versus Communications-Based Prohibitions on Price Fixing." *Journal of Legal Analysis* 3 (2): 449–538.

Krishna, Vijay. 2010. *Auction Theory.* Academic Press: Burlington / San Diego / London.

Leroy, Anne-Marie, and Frank Fariello. 2012. *The World Bank Group Sanctions Process and Its Recent Reforms.* World Bank Publications.

Levenstein, Margaret C., and Valerie Y. Suslow. 2006. "What Determines Cartel Success?" *Journal of Economic Literature* 44:43–95.

Llorente-Saguer, Aniol, and Ro'i Zultan. 2017. "Collusion and information revelation in auctions." *European Economic Review* 95:84–102.

Marshall, Robert C., and Leslie M. Marx. 2007. "Bidder collusion." *Journal of Economic Theory* 133 (1): 374–402.

———. 2009. "The Vulnerability of Auctions to Bidder Collusion." *Quarterly Journal of Economics* 124 (2): 883–910.

———. 2012. *The Economics of Collusion: Cartels and Bidding Rings.* MIT Press: Cambridge / London.

McAfee, R. Preston, and John McMillan. 1992. "Bidding Rings." *American Economic Review* 82:579–599.

Milgrom, Paul R., and Robert J. Weber. 1982. "A Theory of Auctions and Competitive Bidding." *Econometrica* 50 (5): 1089–1122.

Noussair, Charles N., and Gyula Seres. 2020. "The effect of collusion on efficiency in experimental auctions." *Games & Economic Behavior* 119:267–287.

Pesendorfer, Martin. 2000. "A Study of Collusion in First-Price Auctions." *Review of Economic Studies* 67 (3): 381–411.

Porter, Robert H., and J. Douglas Zona. 1993. "Detection of bid rigging in procurement auctions." *Journal of Political Economy* 101:518–538.

———. 1999. "Ohio School Milk Markets: An Analysis of Bidding." *RAND Journal of Economics* 30:263–288.

Seiler, Norbert, and Jelena Madir. 2012. "Fight Against Corruption: Sanctions Regimes of Multilateral Development Banks." *Journal of International Economic Law* 15:5–28.

Skrzypacz, Andrzej, and Hugo Hopenhayn. 2004. "Tacit collusion in repeated auctions." *Journal of Economic Theory* 114 (1): 153–169.

Søreide, Tina, Linda Groning, and Rasmus Wandall. 2016. "An Efficient Anticorruption Sanctions Regime-The Case of the World Bank." *Chicago Journal of International Law* 16:523–552.

Stevenson, Drury D., and Nicholas J. Wagoner. 2011. "FCPA Sanctions: Too Big to Debar?" *Fordham Law Review* 80 (2): 775–820.

Stigler, George J. 1964. "A Theory of Oligopoly." *Journal of Political Economy* 72 (1): 44–61.

Tillipman, Jessica. 2012. "A House of Cards Falls: Why "Too Big to Debar" Is All Slogan and Little Substance." *Fordham Law Review Res Gestae* 80:49–58.

———. 2013. "The Congressional War on Contractors." *George Washington International Law Review* 45:235–251.

Tirole, Jean. 1988. *The Theory of Industrial Organization.* MIT Press: Cambridge / London.

Vickrey, William. 1961. "Counterspeculation, Auctions, and Competitive Sealed Tenders." *The Journal of Finance* 16 (1): 8–37.

World Bank. 2015. *Report on Functions, Data and Lessons Learned, 2007-2015, Second Edition.* Technical report. Office of Suspension and Debarment.

Appendices

A Auction game with fines

In $t = T$, the auction game with fines is equivalent to the benchmark game. In any period $t < T$, the auction game with fines includes the following stages.

- **Stage 0 to Stage 3.** As in the benchmark game.
- **Stage 4**. If a bidding ring is formed, it will be detected with some probability $p = 0.5$. When a bidding ring is detected, its members pay a fine f in $t + 1$.

The equilibrium bidding behavior in the procurement auction and in the PAKT is the same as in the benchmark game, but the collusion decision is affected. In the last period, behavior under fines is the same as behavior under no sanction, as no punishment can occur. In all the previous periods, the expected cost of colluding under fines is positive, whereas the expected cost of colluding under no sanction is zero.

Proposition 3. *Under fines, in $t = T$ the strong bidders will collude, as under no sanction. In any $t < T$, the strong bidders will be less likely to collude under fines than under no sanction. As a result, equilibrium bids will be lower under fines than under no sanction.*

Proof. See Appendix B.3.

B Proofs

B.1 Benchmark game

Proof of Proposition 1

As the benchmark game with no sanction is the same in every period, in what

follows we solve the static game and then analyse a finitely repeated version of it.

Equilibrium bidding behavior if no bidding ring was formed For the general case with any finite n_s and n_w and continuous distributions $F_s(c_{is})$ and $F_w(c_{iw})$, each strong bidder maximizes the expected payoff

$$\begin{aligned}\pi_{is} =&(b(c_{is}) - c_{is}) \Pr(b(c_{is}) < b(\tilde{c})) \\ =&(b(c_{is}) - c_{is}) \Pr(b^{-1}(b(c_{is})) < \tilde{c}) \\ =&(b(c_{is}) - c_{is}) \Pr(c_{ist} < \tilde{c})\end{aligned}$$

where, for $j \neq i$, $\tilde{c} = \min\{c_{js}\}$ denotes the other bidders' lowest cost and thus $b(\tilde{c})$ denotes the minimum competing bid.[31]
Because costs are i.i.d. draws, we have

$$\pi_{ist} =(b(c_{is}) - c_{is})[1 - F_s(c_{is})]^{n_s-1}$$

where $C_{(1)}^{(n-1)}$ denotes the highest first order statistic, i.e. the lowest cost out of $n_s - 1$ independent draws.
Taking the first derivative with respect to c_{is} yields

$$b'(c_i^s)[1 - F_s(c_{is})]^{n_s-1} + (b(c_{is}) - c_i^s)(n_s - 1)[1 - F_s(c_{is})]^{n_s-2}(-f(c_{ist})) = 0 \quad \text{(A1)}$$

Equation (A1) can be rewritten as follows,

$$\frac{\partial}{\partial c_{is}}[b(c_{is})(1 - F_s(c_{is}))^{n_s-1}] = -c_{is}(n_s - 1)[1 - F_s(c_{is})]^{n_s-2} f(c_{is})$$

It follows that the symmetric equilibrium bidding function is

$$b(c_{is}) = \frac{n_s - 1}{[1 - F_s(c_{is})]^{n_s-1}} \int_{c_{is}}^{\bar{c}_s} t[1 - F_s(t)]^{n_s-2} f(t)dt \quad \text{(A2)}$$

In our setting with $n_s = 2$ and $c_{is} \sim U[\underline{c}_s, \bar{c}_s]$, the equilibrium bidding function is given by the following linear function

31. Note that, because $\bar{c}_s < \underline{c}_w$ by assumption and $b(c_{ik})$ is monotonically increasing in c_{ik}, the minimum cost among the other strong bidders and the weak bidders equals the minimum cost among the other strong bidders, $\tilde{c}$.

$$
\begin{aligned}
b(c_{is}) =& \frac{1}{1-\frac{c_{is}-\underline{c}_s}{\bar{c}_s-\underline{c}_s}} \int_{c_{is}}^{\bar{c}_s} t f_s(t) dt \\
=& \frac{1}{\frac{\bar{c}_s-c_{is}}{\bar{c}_s-\underline{c}_s}} \frac{1}{\bar{c}_s-\underline{c}_s} \Big[\frac{t^2}{2}\Big]_{c_{is}}^{\bar{c}_s} \\
=& \frac{1}{2(\bar{c}_s-c_{is})} [t^2]_{c_{is}}^{\bar{c}_s} \\
=& \frac{\bar{c}_s}{2} + \frac{c_{is}}{2}
\end{aligned}
\tag{A3}
$$

Equilibrium bidding behavior if a ring was formed The equilibrium bid of the ring leader is given by:

$$b(c_{is}) = \underline{c}_w$$

The ring leader will not submit a bit above $\underline{c}_w$, as he could be undercut by the weak bidders and lose the auction. He will not submit a bid below $\underline{c}_w$ either, as he could increase his expected payoff by submitting a higher bid.

PAKT The ring leader will earn the equilibrium bid minus the private cost minus the equilibrium side payment to the other ring member:

$$\underline{c}_w - c_{is} - \frac{1}{2}\Big\{\underline{c}_w - c_{is}\Big\} \tag{A4}$$

The other ring member will receive the side payment in equation (4). Thus, both members of the bidding ring will earn the same, i.e.

$$\frac{\underline{c}_w}{2} - \frac{c_{is}}{2} \tag{A5}$$

Proof of Claim 1

Let $\hat{c}_{is}$ and $\tilde{c}_{is}$ denote the private costs of the strong bidders, and assume that $\hat{c}_{is} > \tilde{c}_{is}$. If the highest-cost strong bidder truthfully reveals her type, i.e. if she submits a shill bid, she will receive from the lowest-cost strong bidder (the ring leader) the side payment

$$\frac{\underline{c}_w}{2} - \frac{\tilde{c}_{is}}{2}.$$

If the highest-cost strong bidder pretends to be the lowest-cost strong bidder, in order to be the designated bidder in the procurement auction, then she will earn

$$\underline{c}_w - \hat{c}_{is} - \frac{\underline{c}_w}{2} + \frac{\hat{c}_{is}}{2} = \frac{\underline{c}_w}{2} - \frac{\hat{c}_{is}}{2}. \tag{A6}$$

As $\hat{c}_{is} > \tilde{c}_{is}$ by assumption, it follows that (B.1) is higher than (A6), i.e. the highest-cost strong bidder will have no incentive to mimic the lowest-cost strong bidder.

Collusion decision In the static auction game with no sanction, the expected payoff from not colluding is $\frac{\bar{c}_s}{2} + \frac{c_{is}}{2} - c_{is}$ for the lowest-cost strong bidder, as in equilibrium he will win the competitive procurement auction, and 0 for the highest-cost strong bidder. The expected payoff from colluding is the same for lowest-cost and highest-cost strong bidders,

$$\underline{c}_w - c_{is} - \frac{1}{2}\Big(\underline{c}_w - c_{is}\Big) = \frac{\underline{c}_w}{2} - \frac{c_{is}}{2}$$

Strong bidder i will collude if and only if

$$\frac{\underline{c}_w}{2} - \frac{c_{is}}{2} \geq \pi\Big(\frac{\bar{c}_s}{2} - \frac{c_{is}}{2}\Big) \tag{A7}$$

where π denotes the probability of having the lowest cost.

As $\underline{c}_w > \bar{c}_s$ by assumption and $\pi < 1$, it follows that (A7) holds for any private costs. In the static auction game, strong bidders always collude.

Repeated auction game. As the static auction game has a unique equilibrium, a finitely repeated version of it will have the same equilibrium. It follows that in a repeated auction game with no sanction both strong bidders will collude in each period.

B.2 Auction game with debarment

Proof of Proposition 2

In period $t = T$ of the auction game with one-period debarment, strong bidder i will collude if and only if

$$\frac{\underline{c}_w}{2} - \frac{c_{isT}}{2} \geq \pi\left(\frac{\bar{c}_s}{2} - \frac{c_{isT}}{2}\right) \tag{A8}$$

As $\underline{c}_w > \bar{c}_s$ by assumption and $\pi < 1$, (A8) holds for any private cost c_{isT}. As in the benchmark game with no sanction, both strong bidders will collude.

In period $t = T - 1$, strong bidder i will collude if and only if

$$\frac{\underline{c}_w}{2} - \frac{c_{is,T-1}}{2} + \delta\frac{E(V_T)}{2} \geq \pi\left(\frac{\bar{c}_s}{2} - \frac{c_{is,T-1}}{2}\right) + \delta E(V_T) \tag{A9}$$

where δ denotes the discount factor and $E(V_T)$ denotes the expected value of playing the game in T. Rearranging,

$$\frac{\underline{c}_w}{2} - \frac{c_{is,T-1}}{2} \geq \pi\left(\frac{\bar{c}_s}{2} - \frac{c_{is,T-1}}{2}\right) + \delta\frac{E(V_T)}{2}$$

As the strong bidders will collude in the last period,

$$E(V_T) = \frac{\underline{c}_w}{2} - \frac{E(c_{isT})}{2} > 0$$

In $t = T-1$ the strong bidders will be less likely to collude than in the benchmark game with no sanction.

In $t = T - 2$, strong bidder i will collude if and only if

$$\frac{\underline{c}_w}{2} - \frac{c_{is,T-2}}{2} \geq \pi\left(\frac{\bar{c}_s}{2} - \frac{c_{is,T-2}}{2}\right) + \delta\frac{E(V_{T-1})}{2} \tag{A10}$$

Given symmetry and pure strategies, the probability of colluding in $t = T - 1$ is either 0 or 1. If the probability of colluding is 1,

$$E(V_{T-1}) = \frac{\underline{c}_w}{2} - \frac{c_{is,T-1}}{2} > 0$$

If the probability of colluding is 0,

$$E(V_{T-1}) = \pi\Big(\frac{\bar{c}_s}{2} - \frac{c_{is,T-1}}{2}\Big) > 0$$

In $t = T-2$ the strong bidders will be less likely to collude than in the benchmark game with no sanction. By iteration it can be shown that for any $t < T-2$ the strong bidders will be less likely to collude than in the benchmark game.

Proof of Corollary 1

Let e denote the number of periods the colluding bidders are debarred for. In any period $t \leq T - e$, strong bidder i will collude if and only if

$$\underline{c}_w - c_{ist} \geq \pi(\bar{c}_s - c_{ist}) + \sum_{j=1}^{e} \delta^j E(V_{t+j}) \tag{A11}$$

As e increases, the expected cost from being debarred becomes strictly larger, and thus the expected payoff from not colluding increases. As a result, collusion will become less likely.

When $t > T - e$, the expected cost from being debarred becomes weakly larger (in $t = T$ the increase in e will not make any difference). Thus, collusion will be as likely or less likely.

In a T-period auction game with debarment, the probability of collusion decreases as the length of the debarment increases.

B.3 Auction game with fines

Proof of Proposition 3

In period $t = T$ of the auction game with fines, strong bidder i will collude if

$$\frac{\underline{c}_w}{2} - \frac{c_{isT}}{2} \geq \pi\Big(\frac{\bar{c}_s}{2} - \frac{c_{isT}}{2}\Big) \tag{A12}$$

where π denotes the probability of having the lowest cost. Because $\underline{c}_w > \bar{c}_s$ by assumption, and $\pi < 1$, it follows that (A12) holds for any c_{isT}. Thus, the strong bidders collude for any private costs, as in the benchmark case with no sanction.

In any period $t < T$, strong bidder i will collude if and only if

$$\frac{c_w}{2} - \frac{c_{ist}}{2} + \delta\Big(E(V_{t+1}) - \frac{f}{2}\Big) \geq \pi\Big(\frac{\bar{c}_s}{2} - \frac{c_{ist}}{2}\Big) + \delta E(V_{t+1}) \tag{A13}$$

where $E(V_{t+1})$ denotes the value of playing the game in $t+1$, δ denotes the discount factor and f denotes the fine that the colluding bidders must pay one period after having colluded. Rearranging,

$$\frac{c_w}{2} - \frac{c_{ist}}{2} \geq \pi\Big(\frac{\bar{c}_s}{2} - \frac{c_{ist}}{2}\Big) + \frac{\delta}{2} f \tag{A14}$$

As $f > 0$ and $1 > \delta > 0$, in any period $t < T$ strong bidders are less likely to collude under fines than in the benchmark case with no sanction.

C Additional regressions

C.1 Multilevel models

In addition to our logistic regressions, we also estimate a multilevel model with the following basic specification:

$$Y_{igt} = \beta_0 + \beta_1 DebarLong + \beta_2 DebarShort + \beta_3 Fine + u_{gi} + v_i + \epsilon_{igt}, \tag{A15}$$

where β_0 denotes the constant, *DebarLong*, *DebarShort* and *Fine* are treatment dummies (taking value 1 if i participated in the treatment, and 0 otherwise). The indicator i denotes the second level of clustering, that accounts for 16 observations of each subject i over time, with v_i denoting the subject-specific random effect. The indicator g denotes the third and highest level of clustering, that accounts for each subject nested in a group, with u_{gi} denoting the group-specific random effect. ϵ_{igt} is the error term.

C.2 Bidding dynamics

Figure 5 shows that strong bidders' bids remain relatively stable over time.

Table 10: Impact of sanctions on collusion

DV: Collusion	(1)	(2)	(3)
Baseline: No sanction			
DebarLong	-0.722***	-0.697***	-0.694***
	(0.062)	(0.062)	(0.061)
DebarShort	-0.384***	-0.388***	-0.372***
	(0.080)	(0.075)	(0.071)
Fine	-0.462***	-0.481***	-0.475***
	(0.079)	(0.074)	(0.069)
Cost	no	yes	yes
Risk aversion	no	yes	yes
Demographics	no	no	yes
Wald test	11.99***	10.91***	12.94***
N	1406	1406	1406

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$

Multilevel mixed-effects logit regression. Standard errors in parentheses, clustered at group level. All coefficients are reported as average marginal effects.

Table 11: Impact of sanctions on strong bidders' bids

DV: Bids	(1)	(2)	(3)
Baseline: No sanction			
DebarLong	-32.778***	-31.729***	-30.950***
	(4.620)	(4.624)	(4.374)
DebarShort	-21.895***	-21.695***	-20.654***
	(6.300)	(6.071)	(5.876)
Fine	-32.778***	-31.729***	-30.950***
	(4.620)	(4.624)	(4.374)
Cost		0.632***	0.638***
		(0.059)	(0.059)
Risk aversion		-4.679*	-4.693*
		(2.781)	(2.594)
Demographics	no	no	yes
Wald test	10.01***	9.42***	8.98**
N	1406	1406	1406

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$

Multilevel random effects regression. Standard errors in parentheses, clustered at group level.

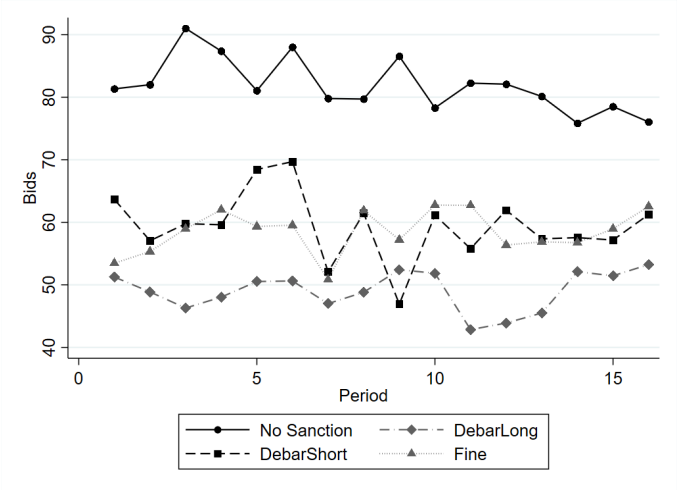

Figure 5: Strong bidders' bids over time.

C.3 N-effects

Subjects stated they would run faster in a 5K run with 50 competitors ($M = 5.193, SD = 2.003$) than in a 5K run with 500 competitors ($M = 4.474, SD = 2.194$). Using a paired t-test, this difference is statistically significant ($p < 0.001$). This difference was consistent across all treatments for 50 competitors (No Sanction: $M = 5.229, SD = 2.004$; DebarLong: $M = 5.104, SD = 1.930$; DebarShort: $M = 5.438, SD = 2.042$; Fine: $M = 5.000, SD = 2.012$) and 500 competitors (No Sanction: $M = 4.646, SD = 2.279$; DebarLong: $M = 4.604, SD = 2.207$; DebarShort: $M = 4.396, SD = 2.254$; Fine: $M = 4.250, SD = 2.007$).

Competitive feelings decreased as the number of competitors increased from 10 ($M = 4.266, SD = 1.873$), to 30 ($M = 3.828, SD = 1.554$), to 50 ($M = 3.422, SD = 1.509$), to 100 ($M = 3.188, SD = 1.816$). Using a paired t-test, the difference between all scenarios is statistically significant ($p < 0.001$). This difference was consistent across all treatments for 10 (No Sanction: $M = 4.250, SD = 1.751$; DebarLong: $M = 4.167, SD = 1.952$; DebarShort: $M = 4.583, SD = 1.968$; Fine: $M = 4.063, SD = 1.774$), for 30 (No Sanction: $M = 3.980, SD = 1.451$; DebarLong: $M = 3.583, SD = 1.567$; DebarShort: $M = 4.000, SD = 1.660$; Fine: $M = 3.750, SD = 1.494$), 50 (No Sanction: $M = 3.625, SD = 1.482$; Debar-

Long: $M = 3.021, SD = 1.362$; DebarShort: $M = 3.479, SD = 1.634$; Fine: $M = 3.563, SD = 1.472$) and 100 competitors (No Sanction: $M = 3.500, SD = 1.815$; DebarLong: $M = 2.854, SD = 1.672$; DebarShort: $M = 2.917, SD = 1.756$; Fine: $M = 3.479, SD = 1.916$).

D Instructions

INSTRUCTIONS

Welcome to this experiment in decision making. Please read the following instructions carefully. You can earn money in this experiment. Your earnings depend on both your decisions and on the decisions of the other participants. At the end of the experiment, the total amount of money earned will be paid to you in cash. In addition, you will receive a fee of 6 Euros for participating in the experiment.

Throughout the experiment, monetary amounts are not quoted in Euro, but in Points. Your total earnings will thus be initially calculated in Points. At the end, the total amount of money earned during the experiment will be converted into Euro, where: 1 Point = 0.10 Euro.

The experiment consists of three parts. It is important that you understand the instructions of each part before you start the experiment. These are the instructions for Part 1. Instructions for Part 2 will be handed out when Part 1 is completed. Instructions for Part 3 will be handed out when Part 2 is completed. Part 1 and Part 2 consist of a sequence of 8 rounds respectively, Part 3 consists of a sequence of 16 rounds.

At the end of the experiment, you will receive EITHER your earnings in Part 1 (8 rounds) plus your earnings in Part 2 (8 rounds) OR your earnings in Part 3 (16 rounds). Whether you receive your earnings in Part 1 plus your earnings in Part 2 OR your earnings in Part 3, will be determined randomly at the end of the experiment. Note that your earnings may be negative in some rounds. However, your accumulated earnings in any Part will never become negative. It is important that you pay the same attention to each part, because each part may be paid out.

Each participant is a bidder in an auction. You will be part of a group of four bidders: you and three other participants. There are two types of bidders: A-bidders and B-bidders. There are two A-bidders and two B-bidders in each group.

All participants receive the same instructions and all decisions are made anonymously. Talking or communicating with other participants is not permitted throughout the entire experiment. Please do not use your cell phones or electronic devices during the experiment. Failure to comply implies exclusion from the experiment and loss of all earnings. If you have any questions or need assistance, please raise your hand. An experimenter will then help you at your desk.

PART 1

Part 1 consists of a sequence of 8 rounds. In each round, you and the three other members of your group participate in an auction. At the beginning of each round, you are assigned the role of either an A-bidder type or a B-bidder type randomly. The composition of your group remains the same throughout the 8 rounds of Part 1.

The outcome of each round is independent from the outcome of previous rounds. This means that your earnings in any given round are not affected by your or other group members' decisions in previous rounds.

In each round, a project is auctioned off. You can submit a bid to obtain the project. The project is awarded to the bidder who submits the lowest bid. If you obtain the project (= win the auction), you earn the amount you bid minus your cost of implementing the project. Your cost will be randomly assigned to you at the beginning of each round. If you do not obtain the project, you earn 0 Points.

Think of this as a situation where you act as an entrepreneur. The auctioneer (for example, the government or a company) is willing to pay an amount of money to an entrepreneur to implement the project. The auctioneer will award the project to the entrepreneur asking for the lowest amount of money. This entrepreneur will receive the amount of money she asked for in the auction (= the bid) minus the cost of implementing the project. The other entrepreneurs who asked for higher amounts will not be awarded the project, and therefore neither receive nor pay anything.

Step 1 At the beginning of each round, you are assigned a random cost. The cost of A-bidders lies between 20 and 60 Points. The cost of B-bidders lies between 80 and 120 Points.

All costs are integer numbers. Each cost has the same probability of being picked. That is, if you are an A-bidder, any cost between 20 and 60 will be assigned to you with the same probability.

Likewise, if you are a B-bidder, any cost between 80 and 120 will be assigned to you with the same probability. The cost assigned to one participant does not depend on the costs of the other participants. Therefore, your cost is probably different from that of the other bidders.

You will be informed about your own cost at the beginning of each round. This value will not be revealed to the other bidders. This also means that you will not be informed about the other bidders' costs.

Step 2 The auction takes place. Each bidder makes one decision: You decide, how much you would like to bid for the project. You can submit any bid in integer numbers between 0 and 140 Points.

All bidders submit their bids at the same time. You will not see the bids submitted by the other bidders before each bidder has submitted her bid. The winner of the auction is the bidder submitting the lowest bid. This bidder thus obtains the project. If two or more bidders submit an equal bid and this bid is the lowest, the winner is chosen randomly among these bidders.

If you win the auction, you receive:

earnings = bid - cost.

If you do not win the auction, you receive:

earnings=0.

Example: Your cost is 20 and you bid 30. If 30 is the lowest bid, you win the auction and receive 10 (= 30 – 20). If 30 is not the lowest bid (for example, another bidder submits a bid of 25), you do not win the auction and receive 0.

Note that you can also incur a loss. This will happen if you submit a bid below your cost and you win the auction with this bid. The amount lost will be subtracted from the earnings you made up to that round. Your final earnings will never be negative, however.

Example: Your cost is 30 and you bid 10. If 10 is the lowest bid, you win the auction. However, your bid being lower than your cost, you earn – 20 (= 10 – 30).

Step 3 The outcome of the auction is communicated to each bidder. You will learn whether you won the auction, which bids were submitted by the other bidders and your earnings in that round.

Step 4 Then a new round will begin. In the new round, you will again bid for an identical project. When a new round begins, each bidder is assigned a new bidder type (A or B) and a new cost. Your bidder type and your cost in one round do not depend on your bidder type and your cost in any other round.

PART 2

Part 2 consists of a sequence of 8 rounds. In each round, you and the other three members of your group participate in an auction, but the rules are different from those in Part 1. At the beginning of each round, you are assigned the role of either an A-bidder type or a B-bidder type randomly. You will be in the same group as in Part 1. You are part of the same group as in Part 1. The composition of your group remains the same throughout the 8 rounds of Part 2.

The outcome of each round is independent from the outcome of previous rounds. This means that your earnings in any given round are not affected by your or others' decisions in previous rounds.

Step 1 At the beginning of each round, you are assigned a random cost. As in Part 1, the cost of A-bidders lies between 20 and 60 Points, and the cost of B-bidders lies between 80 and 120 Points. You will be informed about your own cost at the beginning of each round. The same procedure as in Part 1 applies.

Step 2 Each A-bidder can decide to form an agreement with the other A-bidder. Only A-bidders are offered the option to form an agreement with each other. If you are assigned the role of an A-bidder, the following question appears on your screen: 'Would you like to form an agreement with the other A-bidder in your group?' Each A-bidder can choose Yes or No. An agreement forms if both A-bidders choose Yes. In other words, no agreement is made unless both A-bidders want to make one.

If an agreement forms: If an agreement forms, only one A-bidder can participate in the auction. This A-bidder is called the designated bidder. The A-bidder who does not participate in the auction is called the non-designated bidder.

The designated bidder will be determined as follows: each A-bidder states an amount that she is willing to transfer to the other A-bidder in case she becomes the designated bidder. This amount of money will compensate the non-designated bidder for not participating in the auction (= transfer). The A-bidder stating the higher amount becomes the designated bidder and participates in the auction. The A-bidder stating the lower amount becomes the non-designated bidder. An A-bidder can state any amount between 0 and 120 Points. In case both A-bidders state the same amount, the designated bidder will be determined randomly.

Example: Both A-bidders choose Yes and an agreement forms. You are an A-bidder and state 40 Points, while the other A-bidder states 20 Points. This means: You are the designated bidder. The other A-bidder is the non-designated bidder. An amount of 40 Points is automatically transferred from you to the non-designated bidder. You participate in the auction, the non-designated bidder does not.

Once both A-bidders have stated the amount they are willing to transfer to the other A-bidder in order to become the designated bidder, they will be informed about the amounts they stated, the amount of the transfer and whether they will participate in the auction (= designated bidder) or not (= non-designated bidder). B-bidders will not know whether an agreement has been formed. Then the designated bidder and the B-bidders will proceed to the auction. The designated bidder will submit two bids: one bid for herself and another bid on behalf of the non-designated bidder.

If no agreement forms: If no agreement forms, both A-bidders will learn about it and proceed to the auction with the B-bidders. B-bidders will not know whether an agreement has been formed.

Step 3 The auction takes place.

If an agreement has been formed: If an agreement has been formed, the designated bidder and the B-bidders submit their bids in the auction. In addition to his own bid, the designated bidder submits a bid on behalf of the non-designated bidder. The designated bidder can submit any bid on behalf of the non-designated bidder, as long as this bid is higher than her own bid and below or equal to 140 Points. The earnings of the designated bidder in this round will depend on the transfer made to the non-designated bidder and on whether she wins the auction.

If the designated bidder wins the auction, she receives:

earnings = bid - cost - transfer.

The non-designated bidder receives:

earnings = transfer.

The B-bidders receive:

earnings = 0.

If the designated bidder does not win the auction, she receives:

earnings = 0 - payment.

The non-designated bidder receives:

earnings = transfer.

The B-bidder who wins the auction receives:

earnings = bid - cost.

The other B-bidder receives:

earnings = 0.

If no agreement has been formed: If no agreement has been formed, all bidders submit their bids. The general rules apply: the winning bidder receives her bid minus her cost. The other bidders receive 0 Points.

Step 4 The outcome of the auction is communicated to each bidder. You will learn whether you won the auction, which bids were submitted by the other bidders and your earnings in that round.

Step 5 Then a new round will begin. In the new round, you will again bid for an identical project. When a new round begins, each bidder is assigned a new bidder type (A or B) and a new cost. Your bidder type and your cost in one round do not depend on your bidder type and your cost in any other round.

PART 3 [No sanction] Part 3 consists of a sequence of 16 rounds. In each of these rounds, you participate in an auction. At the beginning of Part 3, you are assigned the role of either an A-bidder type or a B-bidder type randomly. You will keep your bidder type during these 16 rounds. You will not be in the same group as in Part 1 and Part 2. You are now part of a new group, together with 3 participants with whom you have not interacted before. The composition of your group remains the same throughout the 16 rounds.

Apart from that, each round proceeds according rules that are similar to those in Part 2. Differences exist in Step 5.

Step 1 At the beginning of each round, you are assigned a random cost. As in Part 1 and Part 2, the cost of A-bidders lies between 20 and 60 Points. The cost of B-bidders lies between 80 and 120 Points. You will be informed about your own cost at the beginning of each round.

Step 2 A-bidders decide whether to form an agreement.

Step 3 The auction takes place.

Step 4 The outcome of the auction is communicated to each bidder. You will learn whether you won the auction, which bids were submitted by the other bidders and your earnings in that round.

Step 5 At the end of each round, you are asked to guess the other bidders' costs. On your screen, you will be informed about the other bidders' bids. You will then be asked: 'What do

you think: What are the costs of these bidders?' You will state a guess for each of the three other bidders. For each guess, you will receive 2 Points if the distance between your guess and the actual cost is smaller than or equal to 5 Points. If the distance between your guess and the actual cost is larger than 5 Points, you will receive 0 Points.

Then a new round will begin. In the new round, you will again bid for an identical project. When a new round begins, each bidder is assigned a new cost. Your cost in one round will not depend on your cost in any other round. Remember that you will keep your bidder type throughout all 16 rounds.

PART 3 [DebarLong] Part 3 consists of a sequence of 16 rounds. In each of these rounds, you participate in an auction. At the beginning of Part 3, you are assigned the role of either an A-bidder type or a B-bidder type randomly. You will keep your bidder type during these 16 rounds. You will not be in the same group as in Part 1 and Part 2. You are now part of a new group, together with 3 participants with whom you have not interacted before. The composition of your group remains the same throughout the 16 rounds.

Apart from that, each round proceeds according rules that are similar to those in Part 2. Differences exist in Step 4 and Step 6.

Step 1 At the beginning of each round, you are assigned a random cost. As in Part 1 and Part 2, the cost of A-bidders lies between 20 and 60 Points. The cost of B-bidders lies between 80 and 120 Points. You will be informed about your own cost at the beginning of each round.

Step 2 A-bidders decide whether to form an agreement.

Step 3 The auction takes place.

Step 4 If an agreement forms, both A-bidders can be excluded from the game for a duration of six rounds. If the A-bidders are excluded, they will not participate in the auction for the following six rounds. Only the B-bidders will participate in the auction in these six rounds. If the A-bidders are excluded in round 10 or later, they will be excluded for the remaining rounds of Part 3. The A-bidders can only be excluded simultaneously.

The probability of exclusion is 50 %. Note that the A-bidders can only be excluded if an agreement forms. If no agreement forms, the A-bidders cannot be excluded.

Note that you will run the risk of exclusion only for an agreement made in the current round. This means that you will not be excluded in a round if no agreement forms in that round. If you formed an agreement in a previous round, you will not be excluded for this agreement in following rounds.

Both the A-bidders and the B-bidders will know whether the A-bidders have been excluded. When submitting their bids, B-bidders will always know whether the A-bidders are excluded from the auction.

Step 5 The outcome of the auction is communicated to each bidder. You will learn whether you won the auction, which bids were submitted by the other bidders and your earnings in that round.

Step 6 At the end of each round, you are asked to guess the costs of bidders who participated in the auction. On your screen, you will be informed about the bids of these bidders. You will then be asked: 'What do you think: What are the costs of these bidders?'. You will state a guess for each bidder who participated in the auction. For each guess, you will receive 2 Points if the distance between your guess and the actual cost is smaller than or equal to 5 Points. If the distance between your guess and the actual cost is larger than 5 Points, you will receive 0 Points.

Then a new round will begin. In the new round, you will again bid for an identical project. When a new round begins, each bidder is assigned a new cost. Your cost in one round will not depend on your cost in any other round. Remember that you will keep your bidder type throughout all 16 rounds.

PART 3 [DebarShort]

Step 1-3 As in DebarLong.

Step 4 If an agreement forms, both A-bidders can be excluded from the game for a duration of three rounds. If the A-bidders are excluded, they will not participate in the auction for the following three rounds. Only the B-bidders will participate in the auction in these three rounds. If the A-bidders are excluded in round 13 or later, they will be excluded for the remaining rounds of Part 3. The A-bidders can only be excluded simultaneously.

The probability of exclusion is 50 %. Note that the A-bidders can only be excluded if an agreement forms. If no agreement forms, the A-bidders cannot be excluded.

Note that you will run the risk of exclusion only for an agreement made in the current round. This means that you will not be excluded in a round if no agreement forms in that round. If you formed an agreement in a previous round, you will not be excluded for this agreement in following rounds.

Both the A-bidders and the B-bidders will know whether the A-bidders have been excluded. When submitting their bids, B-bidders will always know whether the A-bidders are excluded from the auction.

Step 5-6 As in DebarLong.

PART 3 [Fine] Part 3 consists of a sequence of 16 rounds. In each of these rounds, you participate in an auction. At the beginning of Part 3, you are assigned the role of either an A-bidder type or a B-bidder type randomly. You will keep your bidder type during these 16 rounds. You will not be in the same group as in Part 1 and Part 2. You are now part of a new group, together with 3 participants with whom you have not interacted before. The composition of your group remains the same throughout the 16 rounds.

Apart from that, each round proceeds according rules that are similar to those in Part 2. Differences exist in Step 4 and Step 6.

Step 1 At the beginning of each round, you are assigned a random cost. As in Part 1 and Part 2, the cost of A-bidders lies between 20 and 60 Points. The cost of B-bidders lies between 80 and 120 Points. You will be informed about your own cost at the beginning of each round.

Step 2 A-bidders decide whether to form an agreement.

Step 3 The auction takes place.

Step 4 If an agreement forms, both A-bidders might have to pay a fine of 24 Points. If a fine is imposed, an amount of 24 Points is deducted from the earnings that each A-bidder has made up to that round.

The probability of a fine is 50 %. Note that a fine can only be imposed if an agreement forms. If no agreement forms, the A-bidders are not fined.

Note that you will run the risk of paying a fine only for an agreement made in the current round. This means that you will not have to pay a fine in a round if no agreement forms in that round. If you formed an agreement in a previous round, you will not be fined for this agreement in following rounds.

B-bidders will not know whether the A-bidders have been fined.

Step 5 The outcome of the auction is communicated to each bidder. You will learn whether you won the auction, which bids were submitted by the other bidders and your earnings in that round.

Step 6 At the end of each round, you are asked to guess the other bidders' costs. On your screen, you will be informed about the other bidders' bids. You will then be asked: What do you think: What are the costs of these bidders? You will state a guess for each of the three other bidders. For each guess, you will receive 2 Points if the distance between your guess and the actual cost is smaller than or equal to 5 Points. If the distance between your guess and the actual cost is larger than 5 Points, you will receive 0 Points.

Then a new round will begin. In the new round, you will again bid for an identical project. When a new round begins, each bidder is assigned a new cost. Your cost in one round will not depend on your cost in any other round. Remember that you will keep your bidder type throughout all 16 rounds.

Control Questions

Control questions Part 1

1) Is the following statement correct? In each round of Part 1, you will be matched with different participants. [No]

2) Is the following statement correct? In each round of Part 1, you will be assigned a new role and a new cost. [Yes]

3) Suppose you win the auction. Your cost is 20 and your bid is 40. How much do you earn? [20]

4) Suppose you win the auction. Your cost is 60 and your bid is 30. How much do you earn? [-30]

5) Suppose your cost is 90. Are you an A-bidder or a B-bidder? [B-bidder]

Control questions Part 2

1) Suppose one A-bidder clicks Yes and the other A-bidder clicks No when deciding whether to make an agreement. Is an agreement formed? [No]

2) Suppose you are an A-bidder. An agreement forms. You propose a transfer of 40, the other A-bidder proposes a transfer of 50. Do you submit a bid in the auction? [No]

3) Suppose you are an A-bidder and your cost is 20. An agreement forms and you become the designated bidder. Suppose you transfer 30 to the non-designated bidder, then bid 80 in the auction and win the auction. How much do you earn? [30 (=80-20-30)]

4) Suppose you are an A-bidder and your cost is 20. An agreement does not form. The other A-bidder bids 40. You bid 30 and win the auction. How much do you earn? [10 (=30-20)]

5) Suppose you are an A-bidder and your cost is 60. An agreement forms. You bid 80 in the auction. How much money can you transfer at most to the non-designated bidder without making a loss? [20]

Control questions Part 3 [No sanction]

1) Is the following statement correct? In Part 3, you will be matched with other participants than in Part 1 and Part 2. [Yes]

2) Is the following statement correct? In each round, you will be assigned a new role. [No]

3) Is the following statement correct? In each round, you will be assigned a new cost. [Yes]

Control questions Part 3 [Debarment]

1) Is the following statement correct? In Part 3, you will be matched with other participants than in Part 1 and Part 2. [Yes]

2) Is the following statement correct? In each round, you will be assigned a new role. [No]

3) Is the following statement correct? In each round, you will be assigned a new cost. [Yes]

4) Suppose the A-bidders have been excluded in round 2. How many bidders will submit a bid in the auction in rounds 3, 4 and 5? [2]

5) Suppose an agreement between the A-bidders does not form. Can they be excluded? [No]

6) Can the B-bidders be excluded? [No]

Control questions Part 3 [Fine]

1) Is the following statement correct? In Part 3, you will be matched with other participants than in Part 1 and Part 2. [Yes]

2) Is the following statement correct? In each round, you will be assigned a new role. [No]

3) Is the following statement correct? In each round, you will be assigned a new cost. [Yes]

4) Suppose an agreement between the A-bidders does not form. Can they be fined? [No]

5) Can the B-bidders be fined? [No]