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Debarment and Collusion in Procurement Auctions*

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Abstract

This paper explores the impact of debarment as a deterrent of collusion in first-price procurement auctions. We develop a procurement auction model where bidders can form bidding rings, and derive the bidding and collusive behavior under no sanction, debarment and fines. The model's predictions are tested through a lab experiment. We find that debarment and fines both reduce collusion and bids. The deterrent effect of debarment increases in its length. However, the debarment of colluding bidders reduces efficiency and increases the bids of non-debarred bidders. The latter suggests that the market size reduction resulting from debarment may trigger tacit collusion.

JEL Codes: C92; D03; D44; K21; K42.

Keywords: debarment; collusion; procurement auctions; procurement law; sanctions.

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1 Introduction

Collusion is a pervasive phenomenon in public procurement auctions. Procurement procedures in the provision of infrastructure, education and pharmaceuticals are particularly vulnerable. Collusion in public procurement auctions is harmful, since it reduces competition and increases the cost of public projects. This results in a wasteful use of taxpayer money. On that account, governments and international organizations devote substantial resources to fighting collusion using different legal remedies.

One of the most important remedies used in reaction to collusion and other types of illegal practices in procurement auctions is debarment. Debarment consists of 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 an administrative remedy by US Congress in 1884 with no deterrence function, it was later used by governments and international development banks, such as the World Bank, as a sanction with a clear deterrence purpose. Between 2007 and 2015, the World Bank has debarred more than 360 companies and individuals (The 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 a period of 25 months for engaging in collusive practices under the Bank-financed Pakistan Electricity Distribution and Transmission Improvement Project. 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. In 2009, the World Bank debarred seven firms including China Road and Bridge Corp., China State Construction Corp. and one individual for engaging in collusive practices under a major Bank-financed road infrastructure project in the Philippines. Two debarments were permanent, the others ranged from four to eight years.

Despite its widespread use, evidence on the effects of debarment remains scarce. The only existing study on debarment is theoretical and focuses on its effect on corruption (Auriol and Søreide, 2017). The study shows that debarment 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.[1] However, there is no empirical evidence on the effect of debarment, the main reason being that collusion is difficult to detect. To date, there has been no experimental evidence.

To fill this gap in the literature, we theoretically and experimentally investigate the impact of debarment on explicit and tacit collusion and bidding behavior in a repeated first-price sealed-bid procurement auction.[2] The answer to whether debarment effectively deters collusion is far from obvious. On the one hand, debarment is used as a sanction and should discourage collusive behavior. On the other hand, by reducing the size of procurement markets, it may facilitate collusion and higher bids among non-debarred bidders (Tirole, 1988; Levenstein and Suslow, 2006; Fonseca and Normann, 2012).[3] Hence, debarment may be a double-edged sword: it may trigger the very behavior it aims to deter. To explore the deterrent effect of debarment, we compare debarment with the benchmark case of no sanction, and with fines, which is the most common alternative sanction.[4] In addition, we analyze a short debarment and a long debarment in order to explore how the deterrent effect varies with the length of exclusion. To investigate the collusion-enhancing potential of debarment, we test whether and how the exclusion of colluding bidders affects the bids of non-debarred bidders.

We find that debarments significantly reduce the frequency of collusion and decrease bids towards the competitive level. This deterrent effect increases with the length of the debarment. Similarly, fines strongly decrease collusion and bids. More-

[1] 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).

[2] Explicit collusion, also referred to as bidding rings, is defined as any agreement aimed at limiting competition and sharing the surplus from non-competitive bidding (Marshall and Marx, 2012). Tacit collusion is defined as the coordination of bids in the absence of communication, side-contracting or transfers (Ayres, 1987; Cramton and Schwartz, 2002; Bajari and Yeo, 2009).

[3] Note that, throughout this article, we assume a closed market, i.e. a market with no entry exposing incumbent bidders to competition.

[4] The World Bank has imposed fines in the Siemens case, in which 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).

over, we find that the exclusion of colluding bidders in the short debarment regime increases the bids of non-debarred bidders. This can be interpreted as evidence of tacit collusion. We do not observe this effect under the long debarment. The latter may be explained by the fact that the short debarment was less of a deterrent than the long one: exclusions were twice as frequent. As a consequence, the bidders who remained in the market in the short debarment regime had more time to learn about the additional earning opportunities opened up by the reduced market size. Due to the higher frequency of exclusions, the short debarment leads to lower efficiency levels. Finally, we calibrated our fine so as to be equivalent to the short debarment – as expected, we did not find a significant difference between these sanctions.

To the best of our knowledge, ours is the first theoretical and experimental study on the impact of debarment on collusion in procurement auctions. First, our work contributes to the theoretical analysis of debarment and corruption (Auriol and Søreide, 2017) by exploring the effect on debarment on collusion. Second, our work contributes to the literature on fines in procurement auctions (Hamaguchi et al., 2007) by investigating the effect of debarment within a procurement auction. Third, we contribute to the literature on collusion (Milgrom and Weber, 1982; Porter and Zona, 1993, 1999; Pesendorfer, 2000; Bajari and Ye, 2003; Kaplow, 2011; Fugger et al., 2015; Engel, 2015; Agranov and Yariv, 2016; Brosig-Koch et al., 2016; Noussair and Seres, 2017) by exploring how alternative sanction regimes affect collusive behavior.

The remainder of our article is organized as follows. Section 2 discusses the legal background. Section 3 presents the theoretical model. Section 4 describes our experimental design and testable predictions. 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 debarment as a mere administrative tool

(Tillipman, 2012, 2013). In an administrative 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". In a punitive spirit, the US legislator established a protectionist debarment regime in the *Buy America Act*, 42 U.S.C. Paragraph 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.[5] 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 debarment (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 et al., 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 debarment under the current World Bank sanctions regime not only include corrupt, fraudulent, coercive and obstructive practices but also collusive practices, that is, acts attempting "to simulate competition or to establish bid prices at artificial, non-competitive levels, or are privy to each other's bid prices or other conditions" (Section 1.16 of the World Bank Procurement Guidelines, Section 1.02 of the World

[5]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". Paragraphs 123, 124 of the German Antitrust Act (GWB) transpose the EU Procurement Directive 2014/24/EU, including provisions on statutory and discretionary debarment, into the German legal order.

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 Theory

In this section, we develop a repeated first-price sealed-bid procurement auction with collusion. In the first subsection, we present the benchmark game, i.e. a procurement auction with collusion but no sanction. We solve the static game and show that its results extend to a finitely repeated version. In the second subsection we introduce debarment. In the third subsection, we present the auction game under fines. Note that we consider a repeated game because debarment implies the exclusion of colluding bidders for some periods of the game.

3.1 Benchmark auction game

The auction 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_{ik}, where $i \in \{1, 2\}$, $k \in \{s, w\}$ and $n = n_s + n_w$.[6] 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.

- **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

[6]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.

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.

In what follows, we derive the perfect Bayesian equilibrium of the static game. The game is solved by backward induction.

3.1.1 Procurement auction

Each strong bidder's private cost c_{is} is independently drawn from a distribution $F(c_{is})$ with support $[\underline{c}_s, \bar{c}_s]$, and each weak bidder's private cost c_{iw} is independently drawn from a distribution $F(c_{iw})$ with support $[\underline{c}_w, \bar{c}_w]$, where $\underline{c}_w > \bar{c}_s$. All bidders know their private costs, and the distribution of the other bidders' private costs.

No collusion case. If the strong bidders choose not to form a bidding ring in Stage 1 of the auction game, the last subgame is a competitive auction. Each bidder simultaneously submits a sealed bid b_{ik}, which must be strictly lower than the bidding cap R. The bidder submitting the lowest bid obtains the contract and receives $b_{ik} - c_{ik}$. Each bidder maximizes her profit:

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

The strong bidder's symmetric equilibrium bidding function is (see Appendix A.1 for the derivation):

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

For $n_s = 2$ and $c_{is} \sim U[\underline{c}_s, \bar{c}_s]$, this bidding function is given by:

$$b(c_{is}) = \frac{\bar{c}_s}{2} + \frac{c_{is}}{2} \tag{3}$$

Since $\underline{c}_w > \bar{c}_s$ and the bidding function is monotonically increasing in c_{ik}, the weak bidders' probability of winning is zero. Given that, any bid lower than the cap R will be an equilibrium for weak bidders.

Collusion case. Now consider the subgame reached in Stage 3 if the strong bidders collude in Stage 1. Suppose that the strong bidder with the lowest cost is designated as the ring leader (as shown below, this will be true in equilibrium). The equilibrium bid of the ring leader is given by:

$$b(c_{is}) = E\Big[C_{(1)}^{(n_w)} | C_{(1)}^{(n_s)} > c_{is}\Big] \tag{4}$$

where $C_{(1)}^{(n_k)}$ is the lowest value among $\{c_{1k}, c_{2k}\}$, $k \in \{s, w\}$, i.e. the first order statistic assuming n_k independent draws.[7] The equilibrium bid of the weak bidders is their private cost, i.e. $b(c_{iw}) = c_{iw}$, for $i = \{1, 2\}$. See Appendix A.2 for further detail.

3.1.2 Preauction knock-out

Collusion through bidding rings is not stable in first-price procurement auctions (Stigler, 1964; Marshall and Marx, 2007, 2009). If the lowest cost among bidders is lower than the reservation price set by the government, a bidding ring should agree to submit a single bid close or equal to the reservation price. However, if the lowest-cost bidder can affect the price she receives, she has an incentive to bid above her cost (Vickrey, 1961; Ausubel and Milgrom, 2006). This exposes the lowest-cost bidder to the risk of being undercut by a defecting ring member (Krishna, 2010). To avoid this, side payments can be implemented to induce bidders to truthfully reveal their private costs in a PAKT (McAfee and McMillan, 1992). PAKT have been used by various bidding rings over the last 200 years, covering auctions for antique books, stamps, paintings or farm land (Asker, 2010). In a first-price PAKT, the bid is an offer to operate a side payment to the other ring member (Krishna, 2010). The ring member with the lowest cost submits the winning bid and represents the ring in the procurement auction. The other ring member submits a shill bid. The symmetric equilibrium bid in the PAKT, and thus equilibrium side payment, is given by:

$$\kappa(c_{is}) = \frac{1}{n_s}\Big\{E\Big[C_{[1]}^{(n_w)} | C_{(1)}^{(n_s)} > c_{is}\Big] - c_{is}\Big\} \tag{5}$$

[7] We assume that in case both the ring leader and a weak bidder submit a bid equal to $\underline{c}_w$ or higher, the ring leader will win the auction.

where $C_{(1)}^{(n_k)}$ is the first order statistic of $\{c_{1k}, c_{2k}\}$, $k \in \{s, w\}$.

The ring leader will earn

$$E\Big[C_{(1)}^{(n_w)}|C_{(1)}^{(n_s)} > c_{is}\Big] - c_{is} - \frac{1}{n_s}\Big\{E\Big[C_{[1]}^{(n_w)}|C_{(1)}^{(n_s)} > c_{is}\Big] - c_{is}\Big\}$$

and each other ring member will receive the side payment in equation (5). Thus, all the members of the bidding ring earn the same. For $n_s = 2$, both the ring leader and the other ring member earn

$$\frac{E[C_{(1)}^{(n_w)}|C_{(1)}^{(n_s)} > c_{is}]}{2} - \frac{c_{is}}{2}$$

The equilibrium side payment, i.e. the equilibrium bid in the the PAKT, incentivizes the strong bidder with the highest private cost not to mimic the lowest-cost bidder, as Claim 1 formally states.

Claim 1. *The equilibrium side payment*

$$\frac{1}{n_s}\Big\{E\Big[C_{[1]}^{(n_w)}|C_{(1)}^{(n_s)} > c_{is}\Big] - c_{is}\Big\}$$

is incentive compatible.

Proof. See Appendix A.2. □

3.1.3 Collusion decision

We assume that the strong bidders use the same strategy. A strong bidder will decide to 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.

Proposition 1. *In the static auction game with no sanction, the strong bidders will collude.*

Proof. See Appendix A.2. □

Repeated game. We consider the situation in which the static auction game above is repeated a finite number of periods T. As the static game has a unique equilibrium, the finitely repeated auction game will have the same equilibrium outcome. It follows that in a repeated auction game without debarment, any strong bidder will collude in each period, i.e. Proposition 1 still holds.

3.2 Auction game with debarment

In each period t, the auction game under debarment 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. When a bidding ring is detected, its members are debarred from the auction for $\tau < T$ periods.[8]

Under debarment, the equilibrium bidding behavior in the procurement auction and in the preauction knock-out remain unchanged (see subsection 3.1.1 and subsection 3.1.2). However, the collusion decision is affected.

3.2.1 Collusion decision

Strong bidders. 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. Let $\delta < 1$ denote the exponential discount factor, π the probability that a strong bidder has the lowest cost and Y the expected value of playing the auction game.[9] Assume $n_s = n_w = 2$ and uniformly distributed costs.

[8]In the experiment, we consider both $\tau = 3$ and $\tau = 6$, to explore how the deterrent effect of debarment varies with its length.

[9]In each period t, Y is a function of a strong bidder's cost in that period and his collusion decision. For ease of notation, we omit that.

Proposition 2. *In the dynamic auction game with debarment, the strong bidders will collude if and only if*

$$\frac{E[C_{(1)}^{(n_w)}|C_{(1)}^{(n_s)} > c_{ist}]}{2} \geq p\Big\{\delta Y_{t+1} + \delta^2 Y_{t+2} + ... + \delta^\tau Y_{t+\tau}\Big\} + \pi\frac{\bar{c}_s}{2} + (1-\pi)\frac{c_{ist}}{2}$$

for $\tau \leq T - t$.

Proof. See Appendix A.3. □

Proposition 2 shows that under debarment the strong bidders will collude if the gain from collusion relative to non collusion is weakly larger than the expected cost of being debarred, which is given by the product of the probability of detection and the cost of not playing the auction game for τ periods. The probability of colluding decreases as the probability of detection and the discount factor increase.

3.2.2 Weak bidders.

As discussed in subsection 3.1.1, in case of collusion and in the absence of any sanction weak bidders will bid their private cost c_{iw} in equilibrium. However, under debarment they know that, when the strong bidders are excluded, they are (alone) in a competitive auction and have a chance to win. It follows that their equilibrium bid will be

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

which is strictly higher than c_{iw}.[10] The following remark follows.

Remark 1. The weak bidders' equilibrium bid when strong bidders collude will be higher under debarment than in the absence of any sanction.

3.3 Auction game with fines

In each period t, the auction game with fines includes the following stages.

- **Stage 0 to Stage 3.** As in the benchmark game.

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

- **Stage 4**. If a bidding ring is formed, it will be detected with some probability p. When a bidding ring is detected, its members pay a fine f.

Under fines, the equilibrium bidding behavior in the procurement auction and in the preauction knock-out remain unchanged (see subsection 3.1.1 and subsection 3.1.2). However, the collusion decision is affected.

3.3.1 Collusion decision

A strong bidder will collude if the expected payoff from colluding, conditional on the other strong bidder colluding, is weakly larger than the expected payoff from not colluding.

Proposition 3. *In the dynamic auction game with fines, the strong bidders will collude if and only if*

$$\frac{E[C_{(1)}^{(n_w)} | C_{(1)}^{(n_s)} > c_{ist}]}{2} \geq pf + \pi \frac{\bar{c}_s}{2} + (1-\pi)\frac{c_{ist}}{2}$$

Proof. See Appendix A.4. □

4 Experimental design

The experiment was programmed using the experimental software *z-Tree* (Fischbacher, 2007) and conducted at the BonnEconLab of the University of Bonn, with a total of 236 participants. Subjects were recruited via *hroot* (Bock et al., 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 participants (48 participants per treatment). Before each part of the experiment, participants had to answer control questions in order to proceed to the actual experiment.

The experiment consisted of three parts.[11] Part 1 and Part 2 were common to all treatments. Part 1 consisted of 8 rounds of a procurement auction with no

[11] 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.

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 sanction treatment. Following closely related literature (see Hu et al., 2011), we deliberately increased complexity over these three parts to facilitate subjects' understanding of the game. In particular, Part 1 and Part 2 aimed to let subjects experience respectively a competitive environment and a collusive environment before they faced 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.[12] As 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 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 bidder would never experience collusion before reaching Part 3), and (iii) always-weak bidders feeling 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 they had not previously interacted with (perfect strangers re-matching). 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.

[12]First, if we debarred colluding bidders and then rematched subjects into new groups, we would not be able to observe the effect of debarment on the remaining bidders. Second, due to the exclusion of some strong bidders under debarment, rematching subjects in each round would not guarantee that groups of weak and strong bidders would be formed.

In each treatment, we measured risk preferences (Holt and Laury, 2002), competitiveness and the impact of the number of competitors on competitiveness (Garcia and Tor, 2009; Garcia et al., 2013)[13], 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. On average, subjects earned €17.04.

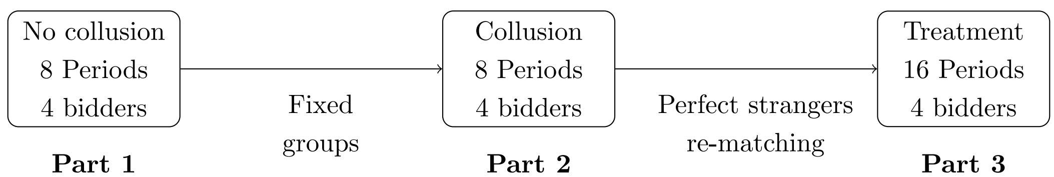

Figure 1: Timeline of the experiment

4.1 Basic game

In this subsection, we describe the steps of the basic game in Part 2. Part 1 is the same as Part 2 but subjects cannot collude. Part 3 is the same as Part 2 but includes sanctions – our treatments – and will be described in the next subsection.[14]

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. The strong bidders then individually and simultaneously decided whether they wanted to form a bidding ring – neutrally referred to as an "agreement". 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.

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

[14] In Part 3, we also elicited the bidders' beliefs about the other bidders' cost, regardless of whether a ring was 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 simultaneously stated the amount 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. Transfers were enforced. Note that in weak bidding rings – such as those involving bid rotation schemes – transfers cannot be enforced. In order to avoid potential confounders 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 also Hu et al., 2011; Noussair and Seres, 2017).

Subsequently, the weak bidder and the designed bidder participated in the procurement auction (the designated bidder submitted her own bid and a shill bid for the non-designated bidder). Tied bids were randomly broken. The bidder placing 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 with no sanction consisted of 16 rounds of the basic game described in the previous section. In the 6-period debarment and the 3-period debarment, bidding rings were detected with a probability of 0.5. In case of detection, the strong bidders were unable to bid in the auction for the 6 rounds or 3 rounds, respectively, following detection.[15] Beliefs were nevertheless elicited, in order not to create 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. This enables us to investigate whether debarment fosters tacit collusion

[15] Strong bidders could be excluded only for a ring formed in the current round, not for a ring formed in a previous round.

among non-debarred bidders. Finally, under fines a bidding ring was detected with a probability of 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 the 3-period debarment, and the detection probability is 0.5, the fine was set to 24 points.

Table 1: Treatments

Treatment	Magnitude	Probability
No sanction		
6-p. debarment	6 rounds	0.5
3-p. debarment	3 rounds	0.5
Fine	24 Points	0.5

4.3 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 (Proposition 1), whereas both under debarments (Propositions 2) and under fines (Propositions 3) strong bidders will collude if and only if the gain from collusion is sufficiently high. This leads to the followings hypotheses.

Hypothesis 1. *The frequency of collusion will be lower under debarment and under fines than in the absence of any sanction.*

Hypothesis 2. *Strong bidders' bids will be lower under debarment and under fines than in the absence of any sanction.*

As discussed, we have calibrated the amount of the fine so as to make it equivalent to the expected cost of a 3-period debarment. Therefore, we expect collusion and bids not to significantly differ between these two sanctions.

Hypothesis 3. *The frequency of collusion will not differ under the 3-period debarment and fines. Similarly, bids will not differ under 3-period debarment and fines.*

Finally, while in the absence of any sanction weak bidders will bid their private cost as they have no chance to win, under debarment they will be alone in a competitive auction and bid competitively (Remark 1).

Hypothesis 4. *Weak bidders' bids will be higher under debarment than in the absence of debarment.*

5 Results

5.1 Summary statistics

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 for a graphical illustration). Similarly, mean bids are higher with no sanction than with debarments or fines, and decrease with the length of the debarment (see Figure 3).[16]

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

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 (see Hu et al., 2011; Bigoni et al., 2012, 2015) and present the results in Appendix B.1. The second level of clustering

[16]Note that in all graphs standard errors are clustered at the group level.

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
6-p. debarment	—	47.099	0.807	72.120	0.226	49.092
3-p. debarment	—	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

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. We do not cluster at higher levels to account for session-specific or time-specific random effects, since there is no reason to expect 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 Wald tests 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, 2016), collusion is a dummy variable taking value 1 when a strong bidder agrees to form a bidding ring, and 0 otherwise. The frequency of collusion is significantly higher with no sanction than under each of the three sanctions (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 characteristics (gender

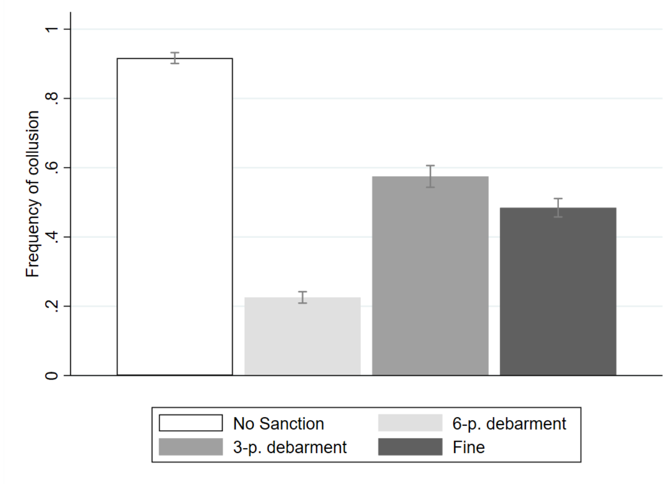

Figure 2: Mean frequency of collusion by treatment

and age).[17] Confirming the results of the parametric and 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. The decrease in collusion generated by debarment increases with its length.

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

The short debarment and the (equivalent) fine reduce collusion to the same extent. The latter comparison is further discussed in subsection 5.4. Risk aversion decreases collusion: more risk averse subjects are more concerned about potential sanctions. Using a three-level random effects model (see Table 10 in Appendix B), we obtain the same results.

5.3.2 Bids

Consistent with our result on the effect of the sanctions on collusion, we find that strong bidders' bids are significantly lower under the debarments and the fine than with no sanction (t-test and Mann-Whitney, $p < 0.01$).[18] Table 4 presents the

[17] Controlling also for the round to account for experience does not change any of the results.
[18] 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			
6-p. debarment	-0.707***	-0.688***	-0.680***
	(0.063)	(0.065)	(0.064)
3-p. debarment	-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

Marginal effect from logit regression. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.
Standard errors in parentheses, clustered at group level.

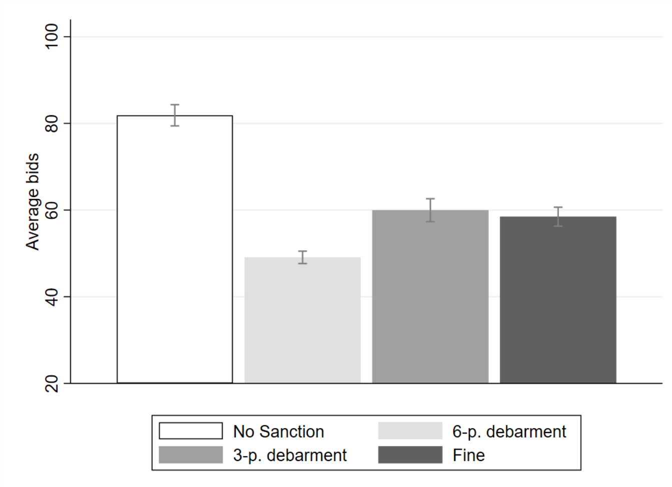

Figure 3: Mean strong bidders' bids by treatment

effect of the sanctions on bids using a linear regression model with standard errors clustered at the group level. Both the debarments and the fine significantly decrease bids, which supports Hypothesis 2.[19] The long debarment decreases bids more than the short one.

Result 2. Strong bidders' bids are lower under debarment and under fines than in the absence of any sanction.

The decrease in bids generated by the fine has a higher magnitude than that generated by a 3-period debarment. This comparison will be further investigated in subsection 5.4. Higher costs lead to higher bids. Risk aversion decreases bids: more risk-averse subjects bid less because they collude less and thus are more concerned about winning the auction in a competitive manner. Using a three-level random effects model (see Table 11 in Appendix B.1), we obtain the same results.

Figure 4 further shows that not only do strong bidders submit higher bids in the absence of sanctions, but some of them submit bids even above the weak bidders' lower cost bound, thereby increasing their own risk of losing the auction. Moreover,

[19]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 this.

Table 4: Impact of sanctions on strong bidders' bids

DV: Bids	(1)	(2)	(3)
Baseline: No sanction			
6-p. debarment	-32.442***	-31.188***	-30.496***
	(4.652)	(4.689)	(4.430)
3-p. debarment	-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

Linear regression. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Standard errors in parentheses, clustered at group level.

we observe that under the 6-period debarment most strong bidders submit bids close to their costs. This indicates that strong bidders – explicit collusion being too risky – did 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 normatively undesirable.

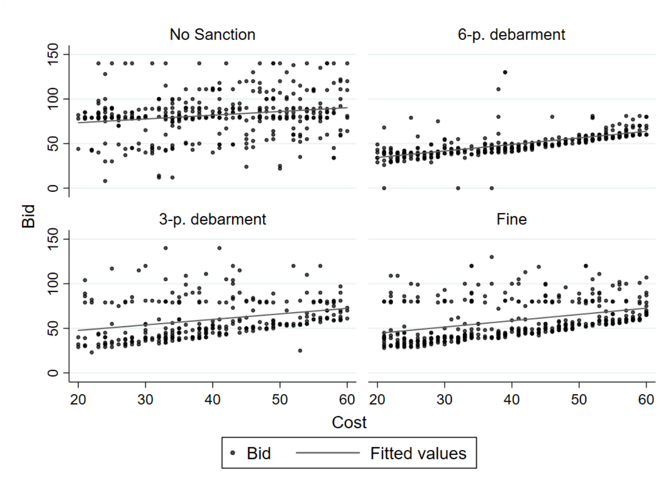

Figure 4: Strong bidders' bids as a function of the costs.

5.4 The comparison between debarment and fines

As discussed, 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 following, we compare the effect of these two sanctions on collusion and strong bidders' bids. Table 5 presents the effect of being subject to the 3-period debarment on collusion (left-hand side of each column) and on bids (right-hand side of each column), as opposed to being subject to the fine. The decrease in collusion and bids generated by the 3-period debarment is not significantly different from that generated by fines. This supports Hypothesis 3.

Result 3. The frequency of collusion and strong bidders' bids are the same under the 3-period debarment and under fines.

Table 5: Effect of 3-period debarment relative to fines

	(1)		(2)		(3)	
DV	Collusion	Bids	Collusion	Bids	Collusion	Bids
Baseline: Fine						
3-p. debarment	-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	

LHS: marginal effects from logit. RHS: OLS. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Standard errors in parentheses, clustered at group level.

Note that, while in the debarment regime strong bidders may lose future and uncertain earnings, in the fine regime they may lose earnings they have already made. If the deterrence of a sanction were affected by the outcome uncertainty that the sanction involves, we should observe a difference between the 3-period debarment and the fine. However, we find no evidence in support of this behavioral effect.

5.5 Weak bidders

In the following, we explore whether the sanctions increased weak bidders' bids, which could be interpreted as evidence of tacit collusion. 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 had an effect on weak bidders' bids (Table 6, left-hand side of each column). When including debarred rounds only, we observe significantly higher bids in the 3-period debarment regime than in the baseline (Table 6, right-hand side of each column). However, the

6-period debarment has no significant impact on bids.[20] Finally, weak bidders' bids do not increase in the fine regime either. Therefore, Hypothesis 4 is supported only for the short debarment.

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 6-period debarment was longer and thus deterred more than the 3-period debarment. As a consequence, debarred rounds were more frequent in the 3-period debarment regime than in the 6-period one. More specifically, strong bidders were debarred in only 40.6 % of all rounds under the long debarment, and in 81.3 % of all rounds under the short one. This implies that weak bidders were not exposed to strong bidders' competition for a much longer time in the short debarment regime, which enhanced their opportunities to figure out how to make additional earnings. In other words, weak bidders' bids are higher in the short debarment regime because its deterrent effect on *strong bidders* is weaker than that of the long debarment regime.

5.6 Earnings and efficiency

5.6.1 Earnings

Strong bidders. Since 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 significantly lower in each of the sanctions regimes (long debarment: 4.260, short debarment: 5.145; fine: 4.430) than in the baseline (15.643), with $p < 0.01$ for t-test and Mann-Whitney test. Table 7 shows that all the sanctions significantly decrease earnings. Strong bidders earned significantly more when a bidding ring was formed than when it was not formed (t-test and Mann-Whitney test, $p < 0.01$).

[20] 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 3-period debarment than under no sanction, but it is not higher under the 6-period debarment than under no sanction.

Table 6: Impact of sanctions on weak bidders' bids

	(1)		(2)		(3)	
DV	All	Debar	All	Debar	All	Debar
Baseline: No sanction						
6-p. debarment	-4.690	-10.422	-3.044	-6.994	-3.245	-7.993
	(5.168)	(9.862)	(5.107)	(7.541)	(5.164)	(6.754)
3-p. debarment	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

LHS: all rounds. RHS: Debarred rounds only. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Linear regression. Standard errors in parentheses, clustered at group level.

Table 7: Impact of sanctions on strong bidders' earnings

DV: Bids	(1)	(2)	(3)
Baseline: No sanction			
6-p. debarment	-11.262***	-10.837***	-10.711***
	(2.184)	(2.278)	(2.038)
3-p. debarment	-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

Linear regression. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

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 the weak bidders' earnings when including all rounds (Table 8, left-hand side of each column). However, when considering debarred rounds only, the 3-period debarment significantly increased weak bidders' earnings relative to the baseline (Table 8, right-hand side of each column).

Table 8: Impact of sanctions on weak bidders' earnings

	(1)		(2)		(3)	
DV	All	Debar	All	Debar	All	Debar
Baseline: No sanction						
6-p. debarment	-2.122	-2.939	-2.140	-3.051	-2.291	-3.481
	(3.312)	(5.227)	(3.233)	(5.119)	(3.248)	(4.571)
3-p. debarment	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

LHS: all rounds. RHS: Debarred rounds only. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Linear regression. Standard errors in parentheses, clustered at group level.

5.6.2 Efficiency

We define efficiency as the ratio $\frac{c_{max} - c_{winner}}{c_{max} - c_{min}}$, i.e. a continuous variable that takes value 1 when the lowest-cost (strong) bidder wins the auction, and lower values when other bidders win.[21] Table 9 shows that the 3-period debarment significantly reduces efficiency, while the other sanctions have no impact on efficiency. The efficiency ratio is 71.9 % under the short debarment, 87.2 % under the long one, 92.3 % under fines and 87.7 % with no sanction.

Table 9: Impact of sanctions on efficiency

DV: Efficiency	(1)	(2)	(3)
Baseline: No sanction			
6-p. debarment	-0.004	-0.009	-0.002
	(0.087)	(0.087)	(0.089)
3-p. debarment	-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	1536	1536

Linear regression. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Standard errors in parentheses, clustered at group level.

This result can be explained by the fact that the short debarment is less deterrent and thus more frequent than the long one. This decreases the probability of the lowest-cost (strong) bidder winning the auction, which drives down efficiency. Debarments of moderate length may hinder efficiency, as they increase the frequency of small markets with high-cost bidders only. If public authorities are concerned with

[21] This measure is equivalent to the one used by Hu et al., 2011.

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, to date their effect on collusion has not been investigated systematically. We fill this gap and explore the impact of debarments on collusion in a repeated first-price sealed-bid procurement auction. We compare debarments with a baseline of no sanction and with fines, and we study 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. Similarly, fines decrease collusion and bids. 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. We do not observe this effect in the long debarment regime, because the long debarment regime deterred twice as much as the short one. Hence, weak bidders interacted in a small market for a longer time in the short debarment regime, which gave them more time to learn how to exploit the absence of the strong bidders' competition. Finally, short debarments reduce efficiency, as the lowest-cost bidder 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 do not sufficiently deter, 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, since contracts will be awarded to higher-cost bidders. Lawmakers and governments concerned with collusion and the efficient allocation of public funds should either opt for debarments that sufficiently deter or for fines. Debarments that are too lenient may facilitate the very behavior they aim to curb.

References

Agranov, M. and L. Yariv (2016). Collusion through Communication in Auctions. Technical report, California Institute of Technology.

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

Auriol, E. and T. Søreide (2017). An economic analysis of debarment. *International Review of Law and Economics 50*, 36–49.

Ausubel, L. M. and P. 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, I. (1987). How Cartels Punish: A Structural Theory of Self-Enforcing Collusion. *Columbia Law Review 87*(2), 295–325.

Bajari, P. and L. Ye (2003). Deciding Between Competition and Collusion. *Review of Economics and Statistics 85*(4), 971–989.

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

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

Bigoni, M., S.-O. Fridolfsson, C. Le Coq, and G. Spagnolo (2012). Fines, Leniency, and Rewards in antitrust. *RAND Journal of Economics 43*, 368–390.

Bigoni, M., S.-O. Fridolfsson, C. Le Coq, and G. Spagnolo (2015). Trust, Leniency, and Deterrence. *Journal of Law, Economics, and Organization 31*, 663–689.

Bock, O., I. Baetge, and A. Nicklisch (2014). hroot: Hamburg registration and organization online tool. *European Economic Review 71*, 117–120.

Brosig-Koch, J., W. Güth, and T. 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, S. M. and F. Wandschneider (2016). Antitrust and the 'Beckerian Proposition': the Effects of Investigation and Fines on Cartels. Technical report, Mimeo.

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

Denes-Raj, V. and S. 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, P. H. (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, P. H. and A. E. Nowlan (2010). Global Administrative Law and the Legitimacy of Sanctions Regimes in International Law. *Yale Journal of International Law 36*, 15–25.

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

Fariello, F. A. and G. 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*, pp. 415–435.

Fariello, F. A. and C. 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, U. (2007). z-tree: Zurich toolbox for ready-made economic experiments. *Experimental Economics 10*, 171–178.

Fonseca, M. A. and H.-T. Normann (2012). Explicit vs. tacit collusion: The impact of communication in oligopoly experiments. *European Economic Review 56*, 1759–1772.

Fugger, N., E. Katok, and A. Wambach (2015). Collusion in Dynamic Buyer-Determined Reverse Auctions. *Management Science 62*(2), 518–533.

Garcia, S. M. and A. Tor (2009). The N-Effect. *Psychological Science 20*, 871–877.

Garcia, S. M., A. Tor, and T. M. Schiff (2013). The psychology of competition. *Perspectives on Psychological Science 8*, 634–650.

Hamaguchi, Y., T. Ishikawa, M. Ishimoto, Y. Kimura, and T. Tanno (2007). An Experimental Study of Procurement Auctions with Leniency Programs. Technical report, Competition Policy Research Center Discussion Paper, Atomi University.

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

Holt, C. A. and S. K. Laury (2002). Risk Aversion and Incentive Effects. *American Economic Review 92*, 1644–1655.

Hu, A., T. Offerman, and S. Onderstal (2011). Fighting collusion in auctions: An experimental investigation. *International Journal of Industrial Organization 29*, 84–96.

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

Krishna, V. (2010). *Auction Theory*. Academic Press: Burlington / San Diego / London.

Leroy, A.-M. and F. Fariello (2012). *The World Bank Group Sanctions Process and Its Recent Reforms*. World Bank Publications.

Levenstein, M. C. and V. Y. Suslow (2006). What Determines Cartel Success? *Journal of Economic Literature 44*, 43–95.

Marshall, R. C. and L. M. Marx (2007). Bidder collusion. *Journal of Economic Theory 133*(1), 374–402.

Marshall, R. C. and L. M. Marx (2009). The Vulnerability of Auctions to Bidder Collusion. *Quarterly Journal of Economics 124*(2), 883–910.

Marshall, R. C. and L. M. Marx (2012). *The Economics of Collusion: Cartels and Bidding Rings*. MIT Press: Cambridge / London.

McAfee, R. P. and J. McMillan (1992). Bidding Rings. *American Economic Review 82*, 579–599.

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

Noussair, C. N. and G. Seres (2017). The Effect of Collusion on Efficiency in Experimental Auctions. Technical report, Mimeo.

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

Porter, R. H. and J. D. Zona (1993). Detection of bid rigging in procurement auctions. *Journal of Political Economy 101*, 518–538.

Porter, R. H. and J. D. Zona (1999). Ohio School Milk Markets: An Analysis of Bidding. *RAND Journal of Economics 30*, 263–288.

Seiler, N. and J. Madir (2012). Fight Against Corruption: Sanctions Regimes of Multilateral Development Banks. *Journal of International Economic Law 15*, 5–28.

Søreide, T., L. Groning, and R. Wandall (2016). An Efficient Anticorruption Sanctions Regime-The Case of the World Bank. *Chicago Journal of International Law 16*, 523–552.

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

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

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

Tillipman, J. (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.

Tillipman, J. (2013). The Congressional War on Contractors. *George Washington International Law Review 45*, 235–251.

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

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

Appendix - For Online Publication

A Proofs

A.1 Benchmark case with no collusion

A.1.1 Equilibrium bid

Strong bidders Each strong bidder maximizes the expected payoff

$$\begin{aligned}\pi_{is} =&(b(c_{is}) - c_{is}) \Pr(b(c_{is}) < b(\tilde{c}))\\ =&(b(c_{is}) - c_{is}) \Pr(b^{-1}(b(c_{is})) < \tilde{c})\\ =&(b(c_{is}) - c_{is}) \Pr(c_{is} < \tilde{c})\end{aligned} \tag{A1}$$

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.[22]

[22]Note that, since $\bar{c}_s < \underline{c}_w$ 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, $\tilde{c}$.

Since costs are i.i.d. draws, we have

$$\pi_{is} = (b(c_{is}) - c_{is})[1 - F(c_{is})]^{n_s - 1} \tag{A2}$$

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

$$b'(c_i^s)[1 - F(c_{is})]^{n_s - 1} + (b(c_{is}) - c_i^s)(n_s - 1)[1 - F(c_{is})]^{n_s - 2}(-f(c_{is})) = 0 \tag{A3}$$

Equation (A3) can be rewritten as follows,

$$\frac{\partial}{\partial c_{is}}[b(c_{is})(1 - F(c_{is}))^{n_s - 1}] = -c_{is}(n_s - 1)[1 - F(c_{is})]^{n_s - 2} f(c_{is}) \tag{A4}$$

It follows that the symmetric equilibrium bidding function is

$$b(c_{is}) = \frac{n_s - 1}{[1 - F(c_{is})]^{n_s - 1}} \int_{c_{is}}^{\bar{c}_s} t[1 - F(t)]^{n_s - 2} f(t)dt \tag{A5}$$

For $n_s = 2$ and a uniform distribution with support on $[\underline{c}_s, \bar{c}_s]$, $F(c_{is}) = \frac{c_{is} - \underline{c}_s}{\bar{c}_s - \underline{c}_s}$ and $f(c_s) = \frac{1}{\bar{c}_s - \underline{c}_s}$. The equilibrium bidding function is given by the following linear function

$$\begin{aligned} b(c_{is}) =& \frac{1}{1 - \frac{c_{is} - \underline{c}_s}{\bar{c}_s - \underline{c}_s}} \int_{c_{is}}^{\bar{c}_s} t f(t) dt \\ =& \frac{1}{\frac{\bar{c}_s - c_{is}}{\bar{c}_s - \underline{c}_s}} \frac{1}{\bar{c}_s - \underline{c}_s} \left[\frac{t^2}{2}\right]_{c_i}^{\bar{c}_s} \\ =& \frac{1}{2(\bar{c}_s - c_{is})} [t^2]_{c_i}^{\bar{c}_s} \\ =& \frac{\bar{c}_s}{2} + \frac{c_{is}}{2} \end{aligned} \tag{A6}$$

Weak bidders Similarly, each weak bidder maximizes the expected payoff

$$\pi_{iw} = (b(c_{iw}) - c_{iw})[1 - F(c_{iw})]^{n_s - 1} \tag{A7}$$

Since $\bar{c}_s < \underline{c}_w$ by assumption and $b(c_{iw})$ is monotonically increasing in c_{iw}, each weak bidder has zero probability to win. Therefore, any bid $b(c_{iw})$ will be an equilibrium.

A.2 Benchmark case with collusion

A.2.1 Equilibrium bid

Strong bidders The equilibrium bid of the ring leader is given by:

$$b(c_{is}) = E\Big[C_{(1)}^{(n_w)} | C_{(1)}^{(n_s)} > c_{is}\Big] \tag{A8}$$

where $C_{(1)}^{(n_w)}$ is the lowest value among $\{c_{1w}, c_{2w}\}$, i.e. the first order statistic assuming n_w independent draws (Krishna 2002). The other strong bidder will submit shill bids.

Weak bidders If the weak bidder i's equilibrium bid is higher than her private cost, i.e. $b(c_{iw}) > c_{iw}$, she will be undercut by a strong bidder and lose the contract. If her equilibrium bid is lower than her private cost, i.e. $b(c_{iw}) < c_{iw}$, she will make a negative profit. Then her equilibrium bid is i.e. $b(c_{iw}) = c_{iw}$.

A.2.2 PAKT

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 bidder truthfully reveals her type, i.e. if she submits a shill bid, she will receive from the lowest-cost bidder (the ring leader) the side payment

$$\frac{E[C_{(1)}^{(n_w)}]}{2} - \frac{\tilde{c}_{is}}{2}. \tag{A9}$$

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

$$E[C_{(1)}^{(n_w)}] - \hat{c}_{is} - \frac{E[C_{(1)}^{(n_w)}]}{2} + \frac{\hat{c}_{is}}{2} = \frac{E[C_{(1)}^{(n_w)}]}{2} - \frac{\hat{c}_{is}}{2}. \tag{A10}$$

As $\hat{c}_{is} > \tilde{c}_{is}$ by assumption, it follows that (A9) is higher than (A10), i.e. the highest-cost bidder will have no incentive to mimic the lowest-cost bidder.

A.2.3 Collusion decision

Proof of Proposition 1

For $n_s = n_w = 2$ and uniformly distributed costs, 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 bidder. The expected payoff from colluding is the same for lowest-cost and highest-cost (strong) bidders,

$$E\Big[C_{(1)}^{(n_w)}|C_{(1)}^{(n_s)} > c_{is}\Big] - c_{is} - \frac{1}{2}\Big\{E\Big[C_{(1)}^{(n_w)}|C_{(1)}^{(n_s)} > c_{is}\Big] - c_{is}\Big\} = \frac{1}{2}\Big\{E\Big[C_{(1)}^{(n_w)}|C_{(1)}^{(n_s)} > c_{is}\Big] - c_{is}\Big\} \tag{A11}$$

Letting π denote the probability that a strong bidder has the lowest cost, a strong bidder will collude if and only if

$$\frac{1}{2}E\Big[C_{(1)}^{(n_w)}|C_{(1)}^{(n_s)} > c_{is}\Big] - \frac{c_{is}}{2} \geq \pi\Big[\frac{\bar{c}_s}{2} - \frac{c_{is}}{2}\Big] \tag{A12}$$

Rearranging,

$$E\Big[C_{(1)}^{(n_w)}|C_{(1)}^{(n_s)} > c_{is}\Big] \geq \pi\bar{c}_s + (1-\pi)c_{is} \tag{A13}$$

As $\underline{c}_w > \bar{c}_s$ by assumption and $E[C_{(1)}^{(n_w)}|C_{(1)}^{(n_s)} > c_{is}] > \underline{c}_w$, then $E[C_{(1)}^{(n_w)}|C_{(1)}^{(n_s)} > c_{is}] > \bar{c}_s$. Moreover, as $c_{is} < \bar{c}_s$ by definition and $\pi < 1$, then $\bar{c}_s + (1-\pi)c_{is} < \bar{c}_s$. It follows that condition (A13) always holds. That is, strong bidders will always collude.

A.3 Debarment

Proof of Proposition 2

For $n_s = n_w = 2$ and uniformly distributed costs, in every period t the lowest-cost (strong) bidder's expected payoff from not colluding is

$$\frac{\bar{c}_s}{2} - \frac{c_{ist}}{2} + \delta Y_{t+1} + \delta^2 Y_{t+2} + ... + \delta^{T-t} Y_T \tag{A14}$$

where $\delta < 1$ denotes the exponential discount factor and Y denotes the expected value of playing the auction game. The highest-cost (strong) bidder's expected payoff from not colluding is

$$\delta Y_{t+1} + \delta^2 Y_{t+2} + \delta^3 Y_{t+3} + ... + \delta^{T-t} Y_T. \tag{A15}$$

The expected payoff from colluding is the same for lowest-cost and highest-cost (strong) bidders,

$$\begin{aligned}&\frac{E[C_{(1)}^{(n_w)}|C_{(1)}^{(n_s)} > c_{ist}]}{2} - \frac{c_{ist}}{2} + p\Big\{\delta^{\tau+1} Y_{t+\tau+1} + ... + \delta^{T-t} Y_T\Big\} + \\ &+ (1-p)\Big\{\delta Y_{t+1} + \delta^2 Y_{t+2} + ... + \delta^{T-t} Y_T\Big\}\end{aligned} \tag{A16}$$

where $\tau < T$ denotes the length of the exclusion.[23]

Letting π denote the probability that a strong bidder has the lowest cost, a strong bidder will collude if and only if

$$\begin{aligned}&\frac{E[C_{(1)}^{(n_w)}|C_{(1)}^{(n_s)} > c_{ist}]}{2} - \frac{c_{ist}}{2} + p\Big\{\delta^{\tau+1} Y_{t+\tau+1} + ... + \delta^{T-t} Y_T\Big\} + \\ &+ (1-p)\Big\{\delta Y_{t+1} + \delta^2 Y_{t+2} + ... + \delta^{T-t} Y_T\Big\} \geq \\ &\delta Y_{t+1} + \delta^2 Y_{t+2} + ... + \delta^{T-t} Y_T + \pi\Big[\frac{\bar{c}_s}{2} - \frac{c_{ist}}{2}\Big]\end{aligned} \tag{A17}$$

Rearranging yields

[23] Note that, if the number of remaining periods, $T-t$, is smaller than τ, τ will have to be set equal to $T-t$.

$$\frac{E[C_{(1)}^{(n_w)}|C_{(1)}^{(n_s)} > c_{ist}]}{2} \geq p\Big\{\delta Y_{t+1} + \delta^2 Y_{t+2} + ... + \delta^\tau Y_{t+\tau}\Big\} + \pi\frac{\bar{c}_s}{2} + (1-\pi)\frac{c_{ist}}{2} \tag{A18}$$

A.4 Fines

Proof of Proposition 3

For $n_s = n_w = 2$ and uniformly distributed costs, in every period t the lowest-cost (strong) bidder's expected payoff from not colluding today is

$$\frac{\bar{c}_s}{2} - \frac{c_{ist}}{2} + \delta Y_{t+1} + \delta^2 Y_{t+2} + ... + \delta^{T-t} Y_T. \tag{A19}$$

The highest-cost (strong) bidder's expected payoff from not colluding today is

$$\delta Y_{t+1} + \delta^2 Y_{t+2} + ... + \delta^{T-t} Y_T. \tag{A20}$$

The expected payoff from colluding is the same for the lowest-cost and highest-cost (strong) bidders,

$$\begin{aligned} &\frac{E[C_{(1)}^{(n_w)}|C_{(1)}^{(n_s)} > c_{ist}]}{2} - \frac{c_{ist}}{2} + p\Big\{(\delta Y_{t+1} - f) + \delta^2 Y_{t+2} + ... + \delta^{T-t} Y_T\Big\} + \\ &+ (1-p)\Big\{\delta Y_{t+1} + \delta^2 Y_{t+2} + ... + \delta^{T-t} Y_T\Big\} \end{aligned} \tag{A21}$$

where f denotes the fine.

Letting π denote the probability that a strong bidder has the lowest cost, a strong bidder will collude if and only if

$$\frac{E[C_{(1)}^{(n_w)}|C_{(1)}^{(n_s)} > c_{ist}]}{2} \geq pf + \pi\frac{\bar{c}_s}{2} + (1-\pi)\frac{c_{ist}}{2}$$

B Additional regressions

B.1 Multilevel models

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

$$Y_{igt} = \beta_0 + \beta_1 6 - p.deb. + \beta_2 3 - p.deb. + \beta_3 Fine + u_{gi} + v_i + \epsilon_{igt},$$

where β_0 denotes the constant, *6-p. debarment*, *3-p. debarment* 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.

Table 10: Impact of sanctions on collusion

DV: Collusion	(1)	(2)	(3)
Baseline: No sanction			
6-p. debarment	-0.722***	-0.697***	-0.694***
	(0.062)	(0.062)	(0.061)
3-p. debarment	-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

Marginal effect from multilevel mixed-effects logit. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.
Standard errors in parentheses, clustered at group level.

B.2 Bidding dynamics

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

B.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 ($p < 0.0001$).

Table 11: Impact of sanctions on strong bidders' bids

DV: Bids	(1)	(2)	(3)
Baseline: No sanction			
6-p. debarment	-32.778***	-31.729***	-30.950***
	(4.620)	(4.624)	(4.374)
3-p. debarment	-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

Multilevel random effects model. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Standard errors in parentheses, clustered at group level.

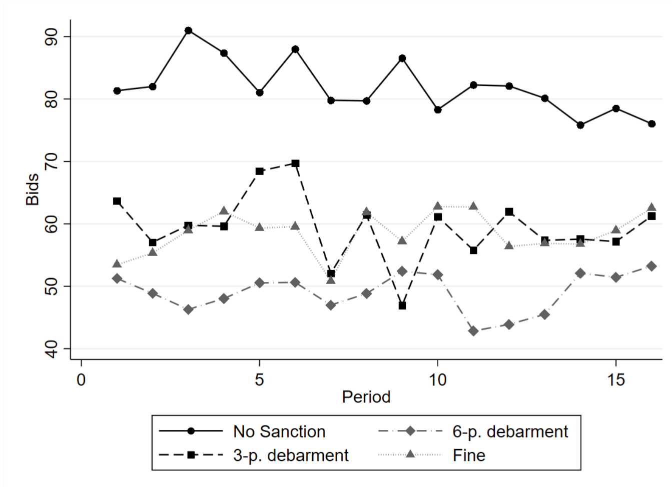

Figure 5: Strong bidders' bids over time.

This difference was consistent across all treatments for 50 competitors (No Sanction: $M = 5.229, SD = 2.004$; 6-p. debarment: $M = 5.104, SD = 1.930$; 3.-p. debarment: $M = 5.438, SD = 2.042$; Fine: $M = 5.000, SD = 2.012$) and 500 competitors (No Sanction: $M = 4.646, SD = 2.279$; 6-p. debarment: $M = 4.604, SD = 2.207$; 3.-p. debarment: $M = 4.396, SD = 2.254$; 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 ($p < 0.0001$).

This difference was consistent across all treatments for 10 (No Sanction: $M = 4.250, SD = 1.751$; 6-p. debarment: $M = 4.167, SD = 1.952$; 3.-p. debarment: $M = 4.583, SD = 1.968$; Fine: $M = 4.063, SD = 1.774$), for 30 (No Sanction: $M = 3.980, SD = 1.451$; 6-p. debarment: $M = 3.583, SD = 1.567$; 3.-p. debarment: $M = 4.000, SD = 1.660$; Fine: $M = 3.750, SD = 1.494$), 50 (No Sanction: $M = 3.625, SD = 1.482$; 6-p. debarment: $M = 3.021, SD = 1.362$; 3.-p. debarment: $M = 3.479, SD = 1.634$; Fine: $M = 3.563, SD = 1.472$) and 100 competitors (No Sanction: $M = 3.500, SD = 1.815$; 6-p. debarment: $M = 2.854, SD = 1.672$; 3.-p. debarment: $M = 2.917, SD = 1.756$; Fine: $M = 3.479, SD = 1.916$).

C 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. Since each Part may be paid out, it is important that you pay the same attention to each.

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 [ContColl] 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 [Debarment6]

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 [Debarment3]

PART 3 [Fines]

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.