The Vulnerability of Auctions to Bidder Collusion

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Abstract

Previous work has addressed the relative vulnerability of different auction schemes to collusive bidding. The common wisdom is that ascending-bid and second-price auctions are highly susceptible to collusion. We show that the details of ascending-bid and second price auctions, including bidder registration procedures, can be designed to completely inhibit, or unintentionally facilitate, certain types of collusion. If auctions are designed without acknowledging the possibility of collusion then the design will ignore key features that impact the potential success of colluding bidders.

Keywords: bidding ring, cartel, auction design, mechanism design
JEL Codes: D44, L4

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1 Introduction

In the economics literature on auctions, it is common to treat ascending-bid auctions and second-price auctions as strategically equivalent (“logically isomorphic” in Vickrey’s (1961) language).\textsuperscript{1} This view extends beyond non-cooperative conduct—the economics literature views ascending-bid and second-price auctions as similarly susceptible to bidder collusion, and for the same reasons.\textsuperscript{2} Bidder collusion is a pervasive problem (see Pesendorfer, 2000) and is an emphasis of competition enforcement. A General Accounting Office Report (GAO, 1990) noted that from 1982 to 1988, over half of the criminal restraint of trade cases filed by the U.S. Department of Justice’s Antitrust Division involved auction markets.

A common theme that emerges from the literature regarding bidder collusion is that a first-price auction is more robust to collusion than either the ascending-bid or second-price auction (see, e.g., Robinson, 1985; Kovacic et al., 2006; and Marshall and Marx, 2007) and this contrast has focused attention on the choice of auction scheme rather than design within a given scheme. Despite the view that opportunities for collusion may be similar in ascending-bid and second-price auctions,\textsuperscript{3} in this paper we show that the two auction formats can differ in terms of their susceptibility to collusion. If an auction designer is concerned about collusion, it needs to pay attention to more than just the choice of the auction scheme. For a given auction scheme, a designer can inhibit or, alternatively, unintentionally facilitate collusion with the specifics of the design. We show that ascending-bid and second-price auctions can be designed to be wholly robust to certain types of collusion. In particular, we focus on

\textsuperscript{1} The economics profession has generally credited Vickrey (1961) with being the first to propose this auction format (see, e.g., Lucking-Reiley, 2000; Rothkopf, Teisberg, and Kahn, 1990; Milgrom, 1989; and McAfee and McMillan, 1987); however, there are examples of the second-price auction being used in practice long before Vickrey’s paper (see, e.g., Lucking-Reiley, 2000; and Moldovanu and Tietzel, 1998).

\textsuperscript{2} See the intuition provided in Marshall and Meurer (2004). At a second-price auction, a cartel has its highest-valuing member bid its value while all other cartel members bid some amount below the auctioneer’s reserve price. Similarly, this same cartel at an ascending-bid auction could have its highest-valuing member remain active up to its value and prevent the other cartel members from meaningfully opposing that bidder. In each case, the highest-valuing cartel member acts just as it would have had the bidding been non-cooperative, and thus there is no incentive for any other cartel member to deviate from the agreement.

\textsuperscript{3} Marshall and Meurer (2004) comment that: “There are two issues antitrust economists recognize as relevant to an analysis of bidder collusion. . . . Second, collusion at an oral ascending bid auction is facilitated by the opportunity for the ring to respond to deviant behavior while the auction is still in progress.”
collusion that does not rely on repeated interaction.

We argue that an auction designer that is concerned about revenue generation should be concerned about the possibility of collusion. Most other design issues, which are typically rooted in results from the non-cooperative auction literature, are focused on relatively small margins around the second-highest valuation. In sharp contrast, by inhibiting collusion the designer can be confident that the second-highest valuation (or something relatively close to it) is what the seller receives as opposed to, say, the fifth, sixth, or tenth highest valuation, which might be the outcome from effective collusion.

A common theme in the auction literature assuming affiliated values is that revenue will be enhanced by designing an auction scheme that reveals as much information as possible during the auction (see, e.g., McAfee and McMillan, 1987; and Milgrom, 2004a). In addition, there may be good economic reasons for greater information disclosure in certain applications. However, these arguments for revealing information presume that collusion is not an issue. We show that the revelation of information during an ascending-bid auction can facilitate collusion. But we also show that some minor changes in the rules of the auction scheme, coupled with careful thought about the information revealed at the time bidders register, can change that result completely, leaving the ascending-bid auction immune to certain types of bidder collusion.

These results are not independent of the mechanisms that conspiratorial bidders use to organize and divide the gains of their collusion. A commonly observed characteristic of many bidding cartels, or rings, is that payments are required only of the cartel member who wins an item, with non-winning cartel members receiving payments from the cartel. An auction designer can take advantage of this aspect of a cartel’s internal mechanism by creating obvious opportunities for the winning cartel member to circumvent payments to its co-conspirators. The cartel will observe

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4For example, in multi-object auctions such as the Federal Communication Commission’s spectrum license auctions, revealing information on bidder identities prior to the auction and on the identities of current high bidders during the auction might provide information about the technological standards that are likely to be adopted, which are relevant for roaming possibilities and the cost of mobile units because of economies of scale (Marx, 2006).

5As an example of a cartel member not making its agreed-to payment to its co-conspirators, see U.S. v. Portac, Inc. (869 F.2d 1288; 1989 U.S. App. LEXIS 2816). As described in that case, three companies conspired to rig bids at a government timber auction known as the “Up and Adam” timber sale held on March 22, 1985. The companies, Portac, Inc., Hoh River Timber Inc., and Astoria Plywood Corp. agreed that Astoria would win the auction, with Portac and Hoh River
these opportunities ex ante and either have to alter its preferred mechanism, or give up on collusion entirely. In the face of anti-collusive design, we provide an alternative mechanism that a cartel would need to adopt to continue colluding successfully. We argue that the implementation of collusion using this mechanism is more difficult and less palatable to a typical bidding cartel.

The paper proceeds as follows. An example from actual auctions is presented in Section 2. The specifics of rules and environments that are often left unspecified with non-cooperative play but which are potentially consequential for collusion are discussed in Section 3, along with the details of our modeling framework. Results are in Section 4, including implications of our findings for collusion deterrence. A summary of the main results is contained in Section 5. Section 6 contains extensions. Section 7 provides concluding discussion.

2 Russian oil and gas lease auctions

As a motivating case, for the past few years the Russian government has held oral ascending-bid auctions for oil and gas leases. The auction rules require that there be at least two bidders at the auction for it to proceed. The Russian government sets a reserve price for each lease and determines the bid increments. The lowest feasible bid is one bid increment above the reserve price. Details of the data and our initial analysis of it are contained in Appendix A.\textsuperscript{6}

Two empirical regularities are worth noting about the Russian oil and gas lease auctions. First, of the auctions with more than two bidders, there often appears to be vigorous competition. Second, in the large plurality of auctions that have only two bidders, many end after submission of only one bid, which is the smallest increment needed to award the lease. In addition, many, but not all, of the bidders that participate in the two-bidder auctions never win any oil or gas leases in our data. In other words, for many of these two-bidder auctions it appears that the second bidder is a shill bidder that is acting as the agent of the winning bidder.

\textsuperscript{6}The data are available on the website for the Center for the Study of Auctions, Procurements and Competition Policy at Penn State: http://econ.la.psu.edu/CAPCP/.
Their presence appears to be motivated solely by the auction rule requiring that at least two bidders be present. The process is such that it may not be clear whether one of the bidders is a shill of the other.

With regard to the design of these auctions, the bidder registration process,\textsuperscript{7} which occurs in advance of the main auction, reveals some but not all information about the bidders. The results below illuminate the importance of the information revealed through the bidder registration process for inhibiting or facilitating collusion.

\section{Model}

Many papers in the economics literature on auctions begin by noting that the four most commonly used and studied auctions are the ascending bid, Dutch, second price, and first price. However, the definitions of these auctions are, with rare exception, not independent of the modeling framework that the author wants to analyze.

For example, if a researcher is interested in the symmetric independent private values (IPV) model with risk-neutral, non-cooperative bidders and a non-strategic auctioneer then for, say, a second-price auction, it suffices to say that it is a sealed-bid auction where the high bidder wins and pays the amount of the second-highest bid. Typically, nothing is typically specified about registration by bidders or whether bidders can submit more than one bid, to name just two common omissions. In practice, multiple registrations may be accomplished through formal or informal agreements with another entity, perhaps specifying the terms of resale following success at the auction.

For the ascending-bid auction there is usually nothing specified about reentry by bidders who have stopped bidding, whether bidders can choose a bid increment, or whether the identities of active bidders are revealed during the bidding, to name just a few typical omissions. These features are not specified because they are expected to be inconsequential to results obtained within a symmetric IPV model with risk-neutral, non-cooperative bidders and a non-strategic auctioneer.\textsuperscript{8} However, a collusive\textsuperscript{7}

\textsuperscript{7}What we refer to as registration corresponds to the application and approval process of the Russian oil and gas lease auctions.

\textsuperscript{8}See Izmalkov (2002) on English auctions with reentry and Avery (2002) on strategic jump bidding at English auctions. Some assumptions are made only to provide for cleaner analytics, such as the assumption that the auctioneer owns the item to be sold, which avoids the introduction of potentially distracting agency analyses.
mechanism must specify bidding behavior by cartel members as well as the division of the collusive gain. Cartel members may need to monitor one another, communicate during the auction, or respond to deviators. Thus, aspects of an auction that are inconsequential for non-cooperative behavior may be material when bidders collude.

3.1 Illustration: FCC spectrum license auctions

As an illustration of this point, several years ago the U.S. Federal Communications Commission (FCC) conducted auctions for spectrum licenses where the bids were large in dollar magnitude, but the FCC had no constraint on the exact magnitude of any bid submitted. When bids are in the hundreds of millions, no non-cooperative bidder is too concerned about the last three digits of its bid. Bidders took little time to realize that the last three digits offered the opportunity for communication with “rivals.” A bid that ended in, say, “012” by a bidder who was active in several regions could be communicating to a “competitor” who was active in similar regions that the first bidder would be willing to stop opposing the second bidder in region “012” if the second bidder stopped opposing the first in the region where it had submitted the “012” bid. In fact, as described in Weber (1997), this kind of communication occurred at the FCC’s PCS A & B Block Spectrum Auction (FCC Auction 4). In the standard symmetric IPV model with risk-neutral, non-collusive bidders and a non-strategic auctioneer, there is no strategic value from the last three digits of a bid, so they are of no concern when working within that modeling environment. However, once the assumption of non-collusive bidders is relaxed, such details become a critical part of the definition of the ascending-bid auction.

3.2 Timing of the model

We are interested in bidding cartels that operate in single-object auction environments, where the bidding is in terms of the price only and where the auctioneer is

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10The data for Auction 4, as well as the other FCC auctions, are available in a unified format on the website for the Center for the Study of Auctions, Procurements and Competition Policy at Penn State: http://econ.la.psu.edu/CAPCP/.
non-strategic except for setting a fixed reserve price \( r \).\(^{11}\)

Other authors have considered bidder collusion in a repeated auction environment. For second-price and ascending-bid auctions, which are the focus of this paper, repetition is not required in order to achieved the first-best collusive outcome if there are no restrictions on the cartel’s ability to collect transfer payments from cartel members (see Proposition 1 below). When there are restrictions on within-cartel transfers, repetition can be useful in supporting collusion,\(^{12}\) but our focus is on how such restrictions, as well as other details of the environment, affect collusion in a one-shot environment.

We model auctions as involving a registration process and a bidding process in which only registered bidders may bid. We assume there are \( n \geq 2 \) auction participants (as opposed to the number of registered bidders, which could be different), and that participants \( \{1, \ldots, k\} \) are eligible to participate in a cartel, where \( 2 \leq k \leq n \). We assume that the identities of the \( k \) cartel participants are common knowledge within the cartel, but that the total number of auction participants \( n \) may not be known to cartel members. Specifically, we assume that either it is known by all that the cartel is all-inclusive, or that it is known by all that the the cartel might not be all-inclusive, in which case we assume cartel members have a common belief distribution over the number of non-cartel bidders, where the distribution is assumed to have unbounded support \( \{0, 1, 2, \ldots\} \).

The timing and description of the stages is as follows:

1. **Cartel formation:** A cartel mechanism is announced (there is commitment to the mechanism). Both potential cartel members and outside bidders observe the mechanism, and potential cartel members join if and only if their expected payoff from participation in the mechanism is greater than their expected payoff from non-cooperative play. All bidders observe whether all potential cartel members join or not.\(^{13}\) If all participants \( \{1, \ldots, k\} \) are eligible to participate in a cartel, where \( 2 \leq k \leq n \). We assume that the identities of the \( k \) cartel participants are common knowledge within the cartel, but that the total number of auction participants \( n \) may not be known to cartel members. Specifically, we assume that either it is known by all that the cartel is all-inclusive, or that it is known by all that the the cartel might not be all-inclusive, in which case we assume cartel members have a common belief distribution over the number of non-cartel bidders, where the distribution is assumed to have unbounded support \( \{0, 1, 2, \ldots\} \).

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\(^{11}\) We assume no resale, but for a discussion of resale in our model, see the working paper version of this paper, Marshall and Marx (2008). See Garratt, Tröger, and Zheng (2007) on the susceptibility of the English auction to collusion when resale is allowed.

\(^{12}\) For results on collusion in repeated auction environments with no transfers and varying assumptions about communication within the ring and the observability of bids see Fudenberg, Levine, and Maskin (1994), Blume and Heidhues (2002 and 2006), Aoyagi (2003), Skrzypacz and Hopenhayn (2004), and Hörner and Jamison (2004).

\(^{13}\) We do not need outside bidders to observe the mechanism used by the cartel, only to infer it correctly in equilibrium. However, in order to use non-cooperative bidding as the benchmark for defining our individual rationality constraint, we do require that outside bidders observe whether the cartel is operating or not, i.e., whether all potential cartel members join.
potential cartel members join, then the cartel mechanism operates and otherwise it
do not, in which case all bidders participate in the auction non-cooperatively.\textsuperscript{14}

2. \textit{Values}: Bidders learn their values. We assume heterogeneous bidders with inde-
dependent private values drawn from distributions with common interval support.\textsuperscript{15}

3. \textit{Cartel mechanism}: If the cartel mechanism is operating, cartel members par-
ticipate in the cartel mechanism. The formal definition of the cartel mechanism is
given in Appendix B, but we can describe the cartel mechanism as follows: Each
cartel member makes a report to a “center,” which is a standard Myerson (1983) in-
centiveless mechanism agent. Based on these reports, the center makes non-binding
registration and bid recommendations privately to each cartel member and announces
the transfer payments to be required after the auction as a function of the reports and
observed outcomes. We require that the center’s budget be balanced in expectation.
The bid recommendations can be functions of information released as part of the
registration and bidding processes as long as the information is available at the time
the bid must be submitted.

4. \textit{Registration process}: Bidders participate in a registration process in which each
bidder chooses how many bidder IDs to request and is randomly assigned that number
of bidder IDs from an infinite set $\mathcal{D}$. Each bidder ID in $\mathcal{D}$ is assigned to at most one
bidder. Thus, for each $i \in \{1, \ldots, n\}$, bidder $i$ has a set $D_i$ of bidder IDs for which it
is the underlying identity. We assume bidder $i$ controls the bidding of all bidder IDs
in $D_i$.

5. \textit{Release of registration-related information}: The auctioneer can release registration-
related information. We assume that any information revealed by the auctioneer must
be accurate, although the auctioneer may choose not to reveal certain information.
The amount of registration-related information that is revealed to bidders depends
on the registration regime (described below) and may or may not reveal the list of
registered bidder IDs or the underlying identities associated with those bidder IDs.

6. \textit{Claiming of bidder IDs}: If the registration-related information released by the

\textsuperscript{14} This is a common simplifying assumption in the auction literature. The assumption affects the
statement of the individual rationality constraint, but is not necessary for the results of this paper.
An alternative assumption is that refusal by one potential cartel member to join implies that the
remaining potential cartel members form a cartel of size $k-1$.

\textsuperscript{15} The heterogeneous independent private values framework has been analyzed by Marshall et al.
have a common interval support simplifies the analysis because, for example, we avoid environments
in which only certain bidders could possibly have a value above the reserve price.
auctioneer does not link bidder IDs to their underlying identities, bidders may claim to have a particular bidder ID, although this is not verifiable. If a cartel member claims a particular bidder ID, then the cartel may use that information. For example, if cartel member \( i \) claims bidder ID \( d \), and if the cartel mechanism requires that a cartel member make a payment to the cartel if it wins the object, then the payment can be collected from cartel member \( i \) if bidder ID \( d \) wins the auction. Bidders cannot credibly communicate that a particular bidder ID is not associated with it.

7. **Bidding process**: Registered bidders participate in the bidding process. The bidding processes we consider are described below. For second-price and ascending-bid auctions, we assume that non-cartel bidders use the non-weakly-dominated strategy of bidding their values.\(^{16}\) We require that, given a particular collusive mechanism, the behavior of the bidders forms a Bayesian-Nash equilibrium. The bidding process may or may not reveal information about the participation and/or bids of the bidders. Any information that is revealed during the bidding process is in terms of the bidder IDs, not their underlying identities.

8. **Cartel transfers**: Any within-cartel transfer payments required by the mechanism are made.\(^{17}\) These transfers can be conditioned on information revealed as part of the registration or bidding process. We assume the cartel can compel cartel members to make their required payments.

### 3.3 Registration regimes

We define three possible registration regimes:

1. **transparent registration** – Prior to the auction, the auctioneer announces the set of all assigned bidder IDs, \( D \equiv \bigcup_{i=1}^{n} D_i \), and their underlying identities, i.e., the auctioneer announces the list \( \{(i, d) \mid i \in \{1, \ldots, n\}, d \in D_i\} \).

2. **semi-transparent registration** – Prior to the auction, the auctioneer announces the set of all assigned bidder IDs, \( D \equiv \bigcup_{i=1}^{n} D_i \), but does not reveal their underlying identities.


\(^{17}\)As in Graham, Marshall, and Richard (1990) and Asker (2007), differential transfer payments are possible to account for heterogeneity among cartel members.
3. **non-transparent registration** – The auctioneer does not reveal the set of assigned bidder IDs nor any information linking bidder IDs with their underlying identities.

These registration regimes are summarized in the following table:

<table>
<thead>
<tr>
<th></th>
<th>list of bidder IDs revealed</th>
<th>bidder IDs linked to the underlying bidder</th>
</tr>
</thead>
<tbody>
<tr>
<td>transparent</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>semi-transparent</td>
<td>yes</td>
<td>no, but IDs can be claimed by the bidders</td>
</tr>
<tr>
<td>non-transparent</td>
<td>no</td>
<td>no, but IDs can be claimed by the bidders</td>
</tr>
</tbody>
</table>

Under transparent registration, bidders know which auction participant is associated with every bidder ID. Thus, if one registrant has more than one bidder ID, that is revealed to all the bidders. Under semi-transparent registration, an all-inclusive cartel can assure itself that no cartel member has multiple bidder IDs if there are exactly $k$ bidder IDs, with each bidder ID claimed by one of the cartel members. Under non-transparent registration, bidders do not even know the set of assigned bidder IDs prior to the auction.

Most FCC spectrum license auctions can be viewed as having transparent registration because the ownership structures associated with bidder identities were made public prior to the auctions. The Russian oil and gas auctions described in Section 2 fall within semi-transparent registration.

### 3.4 Bidding formats

#### 3.4.1 Ascending-bid auctions

A variety of ascending-bid environments are used in practice and in theory. In this paper, we focus on four that are distinguished by whether or not reentry is possible and whether or not the bidder IDs of the active bidders are revealed. We describe these four variations below. In all cases, we assume that if bidders are identified during the auction it is only through their bidder IDs, not the underlying identities behind those bidder IDs.

In many modeling environments, the ascending-bid auction is borrowed from Milgrom and Weber (1982). In that variant, no reentry is possible. Once a bidder ID
withdraws from the bidding it cannot reenter. In addition, the number of active bidders is publicly displayed, but the bidder IDs for the active bidders are not revealed. Following Milgrom and Weber (1982), we refer to this variant as the “Japanese English Auction without identities” or “JEA without identities.” As a variant of the JEA, one could also have the bidder IDs of the currently active bidders revealed during the auction. We refer to this as a “JEA with identities.”

In other ascending-bid formats, reentry is costless and always possible, as is typically the case at many oral ascending-bid auctions. In these formats, it may be possible for bidders to observe the bidder ID of the current high bidder. We will refer to this as the “Standard English Auction with identities” or “SEA with identities.” As a variant of the SEA, bidders might not observe the bidder ID of the current high bidder, for example if Internet-based or telephone bids are allowed or if the bidders are able to disguise the fact that they are bidding. We refer to this as an “SEA without identities.” For example, in some oral ascending-bid livestock auctions, although the identity of the winner is revealed after the auction concludes, the identities of the active bidders and current high bidder are obscured through the use of “ring masters” who accept bids from bidders seated in their assigned areas and transmit those bids to the auctioneer.

We assume that in an SEA, the auctioneer always signals when the bid ascent has stopped and allows some brief period for bidding before closing the auction.

In the ascending-bid formats, the amount of the current high bid is observed by all bidders. In particular, the price paid by the winner is observed by all the bidders. The winning bidder must be able to observe that it has won and losing bidders must be able to observe that they did not win. In a JEA with identities or an SEA with identities, the bidder ID of the winner is revealed through the auction process. In the JEA without identities and the SEA without identities, the bidder ID of the winner may or may not be revealed to all the bidders. In what follows, we will specify whether the bidder ID of the winner is revealed where necessary.

In addition, for studying collusion at ascending-bid auctions it may also be important to specify how bid increments are determined; however, we abstract from this by assuming a continuous price ascent in all of the auction formats we consider.
3.4.2 First-price and second-price sealed-bid auctions

In the standard first-price auction, bidders simultaneously submit bids, with the high bidder winning the object and paying the amount of their bid, as long as the high bid is greater than the reserve price. In the standard second-price auction, bidders simultaneously submit bids, with the high bidder winning the object and paying the amount of the second-highest bid or the reserve price, whichever is higher.

As with the ascending-bid auction formats, at the conclusion of the auction, the winning bidder must be able to observe that it has won and how much it must pay, and losing bidders must be able to observe that they did not win. In contrast to an ascending-bid auction, in a sealed-bid auction, the price paid may only be observed by the winning bidder. However, in what follows, to maintain comparability between sealed-bid and ascending-bid auctions, we assume that at sealed-bid auctions the price paid is observed by all bidders.\(^\text{18}\) In what follows, we will specify where necessary whether the bidder ID of the winner is revealed.

4 Results

4.1 First-best collusive outcomes

For second-price and ascending-bid auctions, the first-best collusive outcome is for the highest-valuing cartel member to win the object whenever its value exceeds that of the highest-valuing outside bidder and to pay the maximum of the reserve price and the highest outside value. In the context of a second-price auction, this is achieved, for example, when the highest-valuing cartel member bids its value and all other cartel members bid below the reserve or do not bid. In the context of a JEA, the first-best collusive outcome is achieved when the highest-valuing cartel member remains active up to its value and all other cartel members exit at a price less than the highest-valuing cartel member’s value and at a price no greater than the price at which the highest-valuing outside bidder exits. In an SEA, the first-best collusive outcome is achieved when the highest-valuing cartel member bids up to its value and non-highest-valuing cartel members do not bid or if the non-highest-valuing cartel members follow

\(^{18}\)In what follows, we consider collusive mechanisms, such as that of Graham and Marshall (1987), that rely on the observability of the price paid. If the price paid were not revealed, mechanisms that rely of this information would not be feasible.
the rule of not bidding when the highest-valuing cartel member is the current high bidder and not bidding when an outside bidder is the current high bidder until the highest-valuing cartel member has had an opportunity to bid.

4.2 No restrictions on payments

If we allow payments from all cartel members, regardless of whether they win the auction, then a bidding cartel can suppress all within-cartel competition at a second-price or ascending-bid auction using the mechanism of Mailath and Zemsky (1991) or Marshall and Marx (2007). The mechanism of Mailath and Zemsky is ex-post budget balanced, but may require payments from multiple cartel members, including those instructed not to bid at the auction. The mechanism of Marshall and Marx is ex-ante budget balanced, but only requires a payment from the highest-reporting cartel member. In that mechanism, the highest-reporting cartel member pays the center an amount equal to the expected surplus that a bidder with value equal to the second-highest report would receive if it were to bid at the auction against the outside bidders, and the expected value of this payment is distributed among all the cartel members so that the mechanism satisfies ex-ante budget balance.

Specifically, in the mechanism of Marshall and Marx (2007), if the reserve price is \( r \), \( \tilde{v}_{out} \) is the random variable equal to the highest value among the bidders outside the cartel (zero if the cartel is all-inclusive), \( \tilde{v}_{in} \) is the random variable equal to the second-highest value among the cartel members, and cartel members submit reports \( s_1 \geq s_2 \geq \ldots \geq s_k \) to the cartel mechanism, then the highest-reporting cartel member, cartel member 1, pays the center

\[
E_{\tilde{v}_{out}} \left( (s_2 - \max\{r, \tilde{v}_1^{out}\}) 1_{s_2 \geq \max\{r, \tilde{v}_1^{out}\}} \right) - p,
\]

where

\[
p \equiv \frac{1}{k} E_{\tilde{v}_{in}} \left( E_{\tilde{v}_{out}} \left( (\tilde{v}_2^{in} - \max\{r, \tilde{v}_1^{out}\}) 1_{\tilde{v}_2^{in} \geq \max\{r, \tilde{v}_1^{out}\}} \right) \right),
\]

and all cartel members other than the one with the highest report receive payment \( p \). Note that the payment made by the highest-reporting cartel member depends only on the second-highest report \( s_2 \). The payment \( p \) is a constant. The mechanism then recommends that the bidder with the highest report bid its report at a second-price auction or bid up to its report at an ascending-bid auction and that all other cartel
members bid some amount below the reserve price. It is an equilibrium for all cartel members to report their values truthfully and follow the bid recommendations of the center. To see this, note that we can view cartel members as competing in a second-price auction for the right to be the sole cartel member to attend the auction. The usual second-price logic implies that it is a best reply for cartel members to report truthfully to the mechanism. Once the mechanism has identified the highest-valuing cartel member, cartel members have no incentive to deviate from the recommended bids. In addition, one can easily show that individual rationality is satisfied strictly.\footnote{This mechanism also satisfies strict interim individual rationality, which applies if cartel members make their participation decisions after learning their values.}

The mechanisms of Mailath and Zemsky (1991) and Marshall and Marx (2007) do not rely on any information from the auction itself and so are not affected by the details of the auctions rules, including registration and bidding procedures.

**Proposition 1** *When a cartel is unrestricted in its ability to collect payments from cartel members, the first-best collusive outcome can be achieved at any second-price or ascending-bid auction, regardless of registration transparency and regardless of auction details.*

The mechanisms of Mailath and Zemsky (1991) and Marshall and Marx (2007) allow first-best collusion at a second-price or ascending-bid auction regardless of whether the identity of the winner or price paid is revealed. However, a cartel might prefer a mechanism that only requires a payment from the highest-valuing cartel member when that cartel member wins the object at the auction. This is particularly relevant for procurement auctions where cartel members may wish to fund transfer payments from auction proceeds or use subcontracting arrangements with other cartel members. The cartel may also prefer payments only from winners if the liquidity required to make the payment will come from the object being sold. In many prosecuted bidding cartels, only the winner made payments to the cartel.\footnote{Examples include: the collectable stamp cartel described in Asker (2007); U.S. v. A-A-A Elec. Co., Inc. (788 F.2d 242; 4th Cir. 1986), where A-A-A did not make payments to its co-conspirators until after receiving final payment from the buyer; U.S. v. Metropolitan Enterprises, Inc. (728 F.2d 444, 1984); and U.S. v. Inryco, Inc. (642 F.2d 290, 1981), where subcontracting arrangements were used to transfer payments between cartel members.} In a number of bidding cartels using post-auction knockouts, only the cartel member ultimately receiving the object made payments to the cartel.\footnote{Examples include those prosecuted in U.S. v. Seville Industrial Machinery Corp., U.S. v. Ronald Pook, and District of Columbia v. George Basiliko.}
In the next section, we consider collusive mechanisms satisfying the restriction that a cartel member can only be asked to make a payment to the cartel if its bidder ID, either one observed to be associated with that cartel member as a result of transparent registration or one claimed by that cartel member, is observed to win the auction.

4.3 Payments only from winners

If the auctioneer or auction process reveals the identity of the winner, then a bidding cartel can condition transfer payments on that information. The mechanism of Graham and Marshall (1987) allows a bidding cartel to suppress all within-cartel competition while only requiring a payment from a cartel member if that cartel member wins the auction. In this mechanism, cartel members make reports to the center and the center recommends that non-highest-reporting cartel members bid below the reserve price at the auction,\(^\text{22}\) while the highest-reporting cartel member bids its report at a second-price auction or up to its report at an ascending-bid auction. If the cartel member wins the auction, it pays the center nothing if the auction price is greater than the second-highest report from the cartel. If the second-highest cartel report exceeds the price paid at the auction, then the winning cartel bidder pays the center the difference between the second-highest report and the price at the auction.

Specifically, if the cartel members submit reports \(s_1 \geq s_2 \geq \ldots \geq s_k\); a cartel member that wins the auction at price \(p\) must pay the center \(\max\{0, s_2 - p\}\). Ex ante budget balance is achieved by having the center make a payment to each cartel member equal to \(1/k\) times the expected revenue to the center as a result of payments by winning cartel members.

Given this payment rule, a cartel member has no incentive to over report because if doing so makes the difference between the cartel member’s report being highest and not, then it means that the second-highest report is greater than the cartel member’s value, and then the payment rule guarantees that the cartel member will have to pay an amount greater than its value if it wins the object. Similarly, there is no incentive to under report because if doing so makes the difference between the cartel member’s report being highest and not, then since the highest-reporting cartel member bids

\(^{22}\text{Graham and Marshall (1987) describe optimal “disguised” bids by the }k-1\text{ lowest-valuing cartel members. These meaningless “competitive” bids are submitted by the cartel so that the auctioneer cannot infer whether bids are coming from a cartel or non-cartel bidder.}\)
truthfully at the auction, the deviating cartel member obtains no collusive gain.

We assume that any results of the bidding process that are made available to the bidders are done so only using the bidder IDs, not the underlying identities behind those bidder IDs. Thus, when we say that a cartel can only collect payments from a cartel member that wins the auction, we mean that in semi-transparent and non-transparent registration regimes, the cartel can only collect payments from a cartel member if that cartel member claims a bidder ID $d$ during the “claiming of bidder IDs” phase and bidder ID $d$ is observed to win the auction.

**Proposition 2** When a cartel can only collect payments from a cartel member that wins the auction, the first-best collusive outcome can be achieved at any second-price or ascending-bid auction that has transparent registration and that reveals the winning bidder ID.

*Proof.* In this environment (transparent registration and the auctioneer reveals the winning bidder ID), the cartel can identify whether a particular cartel member has won the auction. In an ascending-bid auction, bidders observe the price paid as part of the bidding process, and in a second-price auction we assume the auctioneer reveals the price paid. Thus, the cartel can use the mechanism of Graham and Marshall (1987) to achieve the first-best collusive outcome. Q.E.D.

Proposition 2 shows that under transparent registration, a restriction that the cartel only collect a payment from a cartel member who wins does not affect the profitability of collusion if the identity of the winner is revealed. However, if information suppression by the auctioneer, shill bidding, multiple registrations, subcontracting, or other arrangements interfere with the ability of cartel members to learn the true identity of the winner, then the result changes.

**Proposition 3** When a cartel can only collect payments from a cartel member that wins the auction, the first-best collusive outcome cannot be achieved at a second-price auction or ascending-bid auction without identities (JEA or SEA) that has non-transparent registration (even if the auctioneer reveals the winning bidder ID).

*Proof.* Assume a second-price auction with non-transparent registration, and consider a collusive mechanism that achieves the first-best collusive outcome and that only collects payments from a cartel member that wins the auction. Relying on the
Revelation Principle, assume the mechanism is incentive compatible both in terms of the truthful revelation of values and obedience to the mechanism’s recommended registration and bidding behavior (see Myerson, 1985). To achieve the first-best collusive outcome, the highest-valuing cartel member must bid its value and non-highest-valuing cartel members must bid below the reserve price or not bid. (If the cartel is all-inclusive, then the first-best collusive outcome can also be achieved by having the highest-valuing cartel member bid above its value.) If the cartel does not require any payments from cartel members, then a cartel member with value greater than the reserve price can profitably deviate by reporting a value equal to the upper support of the value distribution and then bidding its value at the auction. In this case, since we assume all bidders have a common upper support of their value distributions, all other cartel members would be instructed by the cartel to bid below the reserve price or not bid, and so the deviation would increase the deviating cartel member’s payoff whenever its value was greater than those of the outside bidders but not the highest in the cartel. Thus, with positive probability the collusive mechanism must require a payment from a cartel member that wins the auction.

But if a cartel member has a positive expected payment to the cartel in the event that it wins the auction, and no payment if it does not win, then a cartel member can profitably deviate by reporting a value equal to the upper support of the its value distribution and also registering a bidder ID that it does not reveal to the cartel (with non-transparent registration, no inference is possible by the cartel regarding multiple registrations by its members). The deviating cartel member can use that bidder ID to bid its value at the auction, while bidding zero with any other bidder IDs it has. The deviation allows the deviating cartel member to avoid having to make a payment to the cartel and is profitable whenever the cartel member’s value is greater than those of the outside bidders.

Because the JEA without identities and SEA without identities provide no information during the auction process that can be used to identify the current high bidder, the proof for those auction formats proceeds as in the case of a second-price auction. Q.E.D.

Proposition 3 shows that rules exist for second-price auctions and ascending-bid auctions without identities that prevent a cartel from achieving the first-best collusive outcome using a mechanism that only collects payments from a cartel member.
that wins the auction. When cartel members can register bidders whose underlying identities cannot be traced to them, cartel members prefer to use such a bidder to avoid having to make a payment to the center in the event that they win. Thus, first-best collusion cannot be sustained. In particular, with non-transparent registration, the mechanism of Graham and Marshall (1987) no longer works because the highest-valuing cartel member can use a bidder ID that is not recognized by the cartel and thereby avoid having to make a payment to the cartel. In the environment of Proposition 3, correlating devices with no transfers are the only available mechanisms for collusion in a one-shot environment. Although the cartel cannot achieve the first-best collusive outcome, the cartel mechanism can still play the role of an equilibrium selection device if there are multiple equilibria and can allow the cartel to implement correlated equilibrium.\footnote{If within-cartel payments can only be required from a cartel member who wins the auction, and if the auction process does not reveal the underlying identity of the winner, then a cartel member winning the auction has no incentive to pay (absent repeated-game incentives). Thus, if the auction process does not reveal the underlying identity of the winner, a cartel at a second-price auction must rely on correlated equilibria with no transfers among cartel members. For more discussion of this case, see the working paper version of this paper, Marshall and Marx (2008). For the development of this type of mechanism in an environment with resale, see Garratt, Tröger, and Zheng (2007).}

Comparing Propositions 2 and 3, we see that there may be an incentive for a cartel to convert non-transparent registration to transparent registration if possible. For example, at the FCC’s Nationwide Narrowband (PCS) Auction (FCC Auction 1), the FCC’s intention was to hold an ascending-bid auction with identities, but with non-transparent registration. However, bidders were able to observe movements in and out of bidding booths and connect those with the timing of the posting of bids to figure out which bidder IDs were associated with which auction participants.

The following proposition considers semi-transparent registration. With a non-all-inclusive cartel, the proposition’s result depends on whether non-cartel bidders, i.e., bidders that are truly independent non-cartel bidders, can and do identify themselves and claim their bidder IDs in a credible way. When a cartel member claims a bidder ID, they commit to making any payments required based on the observed bidding behavior of that bidder ID, but when a non-cartel member claims a bidder ID, that information is only useful to the cartel if it represents a credible statement that the claimed bidder ID is not actually the bidder ID associated with one of the cartel members, so the credibility of the claim becomes important.
Proposition 4 When a cartel can only collect payments from a cartel member that wins the auction, the first-best collusive outcome cannot be achieved at a second-price auction or ascending-bid auction without identities (JEA or SEA) that has semi-transparent registration and that reveals the winning bidder ID unless the cartel is all-inclusive or the cartel is not all-inclusive and all non-cartel participants identify themselves and claim their bidder IDs in a credible way.

Proof. If the cartel is all-inclusive or the cartel is not all-inclusive and all non-cartel participants identify themselves and claim their bidder IDs in a credible way, then the cartel can achieve the first-best collusive outcome by recommending reversion to non-cooperative bidding with no transfers unless it is observed that all bidder IDs are claimed by a cartel member or outside bidder. If all bidder IDs are claimed, then bidding and transfers are defined as in Graham and Marshall (1987). In this environment, a cartel member cannot profitably deviate by registering a bidder ID that it does not claim in an attempt to avoid having to make a payment to the cartel because that deviation would result in an unclaimed bidder ID and, thus, reversion to non-cooperative bidding. However, if the cartel is not all-inclusive and non-cartel participants either cannot or do not credibly identify themselves and credibly claim their bidder IDs, then as in the proof of Proposition 3, the first-best collusive outcome cannot be achieved because any mechanism achieving the first-best collusive outcome is vulnerable to deviations in which a cartel member registers a second bidder ID that it does not claim but that it uses to submit its bid.

Because the JEA without identities and SEA without identities provide no information during the auction process that can be used to identify the current high bidder, the proof for those auction formats proceeds as in the case of a second-price auction. Q.E.D.

Comparing the results of Propositions 2, 3, and 4 for second-price auctions, we have the following result.

Corollary 1 At a second-price auction or ascending-bid auction without identities, transparent registration can be pro-collusive relative to semi-transparent registration, which can be pro-collusive relative to non-transparent registration.

A second-price or ascending-bid format that releases detailed information about the registered bidders prior to the auction can be pro-collusive because it can allow
a cartel to police attempts by cartel members to set up alternative bidder identities that might allow them to disrupt the ability of the collusive mechanism to collect payments from a winning cartel member.

Corollary 1 suggests that subcontracting and resale agreements arranged prior to an auction might be anti-collusive if they establish a second identity under which a cartel member can bid without being recognized as the underlying identity. However, such arrangements can be pro-collusive in other contexts, such as if subcontracting can be used to implement transfer payments among cartel members (see Kovacic et al., 2006).

In contrast to the above results, at an ascending-bid auction with identities the presence of bidders whose underlying identities cannot be observed need not eliminate the possibility of first-best collusion. In some environments, we can construct a collusive mechanism, which we refer to as a “responsive to outside bidders” or “ROB” mechanism, that employs the payment scheme of Graham and Marshall (1987) but requires active bidding by non-highest-valuing cartel members and thereby restores the possibility of first-best collusion at ascending-bid auctions when registration is not transparent.

In the case of a JEA with identities, the ROB mechanism instructs the cartel members to claim their bidder IDs and instructs non-highest-valuing cartel members to stay active up to their values or until the last bidder that is not identifiable as a cartel member exits, whichever comes first. Under this mechanism, if a cartel member attempts to win the object using an unclaimed identity to avoid making a payment to the cartel, the other cartel members remain active up to their values and there is no collusive gain.

In the case of an SEA with identities, the ROB mechanism once again instructs the highest-valuing cartel member to reveal its bidder ID to the other cartel members, and it instructs the non-highest-valuing cartel members to bid if the price is less than their values and the auctioneer has signaled that the auction is about to close and the current high bidder is not identifiable as the highest-valuing cartel member. The highest-valuing cartel member is instructed to bid promptly whenever it is not the current high bidder and the price is less than its value. Again, under this mechanism, if the highest-valuing cartel member attempts to win through a disguised identity to avoid making payments to the cartel, the collusive gain is lost because the other cartel members bid up to their values.
Under the ROB mechanism, cartel members bid up to their values as long as they perceive competition from bidder IDs not claimed by the cartel, and this deters deviations based on disguised identities.

**Proposition 5** When a cartel can only collect payments from a cartel member that wins the auction, the first-best collusive outcome can be achieved at a JEA with identities or an SEA with identities, even with semi-transparent or non-transparent registration.

As shown in Proposition 5, the cartel’s ability to eliminate cartel members’ use of disguised identities as a profitable strategy at ascending-bid auctions does not depend on whether reentry is possible—effective cartel strategies exist for both the JEA with identities and the SEA with identities, namely the ROB mechanism. As this argument shows, in both a JEA and SEA with identities, auction rules may permit cartel strategies that prevent disguised identities from being used by cartel members to cheat on the cartel. In such environments, these ascending-bid auctions are more susceptible to collusion than a second-price auction.

**Corollary 2** The susceptibility of ascending-bid auctions to collusion depends on whether the auctions are with or without identities but not on whether reentry is allowed (SEA allows reentry and JEA does not).

Proposition 5 contrasts with Propositions 3 and 4 and shows that in some environments ascending-bid auctions are more susceptible to collusion than second-price auctions.

**Corollary 3** With non-transparent registration and in some cases with semi-transparent registration, ascending-bid auctions with identities are more susceptible to collusion than second-price auctions.

Because the economics literature on bidder collusion has typically focused on transparent registration, the result of Corollary 3 is in stark contrast with some existing results. For example, Graham and Marshall (1987, p.1234) state: “Models of single-object second-price and English auctions have been proposed in which cooperative behavior is permitted and in which the auctioneer is allowed to respond strategically to such behavior. ... Therefore, the revenue equivalence result for the
second-price and English auctions within the IPV context extends to cooperative behavior.” As Corollary 3 shows, the revenue equivalence result does not extend to cooperative behavior in environments with non-transparent or semi-transparent registration.

4.4 Implications for bid data

In the ROB mechanism described in the previous section, at a JEA one would expect to observe cartel members exiting the auction at the same time as the last outside bidder. Traces of this simultaneous exit might be detected in bid data. For example, a paper submitted to the U.S. Federal Communications Commission (FCC) by Gregory Rose (2007, Table 11) alleges that in FCC Auction 66 for Advanced Wireless Services, there was a mass simultaneous exit of incumbent wireless providers at the point when Wireless DBS LLC exited the bidding for the large F Block spectrum licenses. Although there are many possible explanations for the bidding behavior at FCC Auction 66, this example demonstrates that such bidding behavior potentially can be detected through a retrospective analysis of the data.

4.5 Auction comparisons

The results discussed above show that one auction format may be more or less susceptible to collusion depending on the details of the auction rules and environment as well as the strength of the cartel, in particular the cartel’s ability to collect payments from its members. The difference between the second-price and ascending-bid auction formats arises when the cartel restricts attention to mechanisms in which only the winner pays and when the use of disguised identities is possible. Differences within ascending-bid formats depend on the informational environment, i.e., whether or not it is an ascending-bid auction with information or without information, but not the ability to reenter or not, i.e., collusive opportunities are the same at a JEA and an SEA as long as both are with information or both are without information.

Suppose a cartel is restricted only to collect payments from a cartel member that wins the object. Under non-transparent registration with a non-all-inclusive

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24Wireless DBS was a joint venture of the two leading satellite TV companies, and was considered the main potential new competitor to the existing wireless providers, particularly those with a national footprint.
cartel, then at either an ascending-bid auction without identities or at a second-price auction, the cartel can do no better than a random assignment mechanism with no transfers and cannot achieve the first-best collusive outcome (see footnote 23). But if we modify the ascending-bid format so that the identities of the active bidders or identity of the current high bidder is revealed, then the first-best collusive outcome is possible at the ascending-bid auction but not at the second-price auction. If instead we modify the second-price auction to have transparent registration, then the first-best collusive outcome is possible at the second-price auction but not at the ascending-bid auction. This highlights how the details of the registration and bidding rules together determine the susceptibility to collusion.

This idea extends to the first-price auction, which is widely viewed as less susceptible to collusion than a second-price auction. If a bidding cartel can control the bids of its members, such as preventing all but one of the cartel members from bidding at the auction (see McAfee and McMillan, 1992), and there is transparent registration, then profitable collusion is possible at the first-price auction, and the profitability of collusion in this setting may be greater than the profitability of collusion at a second-price auction with non-transparent registration.

So, statements regarding the relative susceptibility of auction schemes to collusion require that we specify registration and bidding rules, as well as the mechanism used by the cartel.

5 Summary of results

Table 2 summarizes the results of the paper. As shown by the last column of the table, in an environment with transparent registration, the auction formats we consider are all equally susceptible to collusion. But reading down the other columns, we see that for other registration regimes, auction design decisions can affect the susceptibility of the auction to collusion. Reading across the rows, we see that for a given auction format, the registration regime can affect the susceptibility of the auction to collusion. Finally, in some cases comparisons “along the diagonal” in the table may be relevant. For example, if a given auction format necessitates a particular registration regime, then the relevant comparisons involve changes in both the auction format and the

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25See Lopomo, Marx, and Sun (2008) for an analysis of the inability of bidders to collude profitably at first-price auctions when the cartel cannot prevent its members from bidding at the auction.
registration regime.

Table 2: Summary of results

<table>
<thead>
<tr>
<th>Can the first-best collusive outcome be achieved?</th>
<th>Non-transparent registration</th>
<th>Semi-transparent registration</th>
<th>Transparent registration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unrestricted ability to collect payments</td>
<td>yes (Prop. 1)</td>
<td>yes (Prop. 1)</td>
<td>yes (Prop. 1)</td>
</tr>
<tr>
<td>Restricted to payments only from winners</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ascending with IDs (JEA or SEA)</td>
<td>yes (Prop. 5)</td>
<td>yes (Prop. 5)</td>
<td>yes (Prop. 2)</td>
</tr>
<tr>
<td>ascending without IDs* (JEA or SEA)</td>
<td>no (Prop. 3)</td>
<td>no (Prop. 4) (exceptions**)</td>
<td>yes (Prop. 2)</td>
</tr>
<tr>
<td>second price</td>
<td>no (Prop. 3)</td>
<td>no (Prop. 4) (exceptions**)</td>
<td>yes (Prop. 2)</td>
</tr>
</tbody>
</table>

*Assume the auctioneer reveals the identity of the winner.
**Yes, if the cartel is all-inclusive or all outside bidders credibly identify themselves and claim their bidder IDs.

The results shown in Table 2 that are based on Proposition 1 are supported by the collusive mechanism of Marshall and Marx (2007), which involves transfer payments that do not depend on the outcome of the auction and may be required of a cartel member that does not win the auction. The results based on Proposition 2 are supported by the collusive mechanism of Graham and Marshall (1987), which involves a transfer payment only from a ring member that wins the auction. The other two “yes” results in Table 2, which are based on Proposition 5, are supported by the ROB collusive mechanism described in Section 4.3, which requires that all cartel members participate in the auction and bid in a way that does not reduce the collusive gain, but does prevent bidders IDs not recognized as belonging to a cartel member from being able to win the auction at a price less than the values of the cartel members. The negative results in Table 2, which reference Propositions 3 and 4, are novel results in that the literature on bidder collusion typically views ascending-bid and second-price auctions as susceptible to collusion, a view which we show follows from the literature’s focus on transparent registration.
6 Extensions

Below we consider two extensions. Section 6.1 considers the case in which no within-cartel transfers are allowed, and Section 6.2 considers the case in which resale is possible.

6.1 Mechanisms with no payments

If ring payments can only be required from a ring member who wins the auction, and if the auction process does not reveal the bidder ID of the winner, then a ring member winning the auction has no incentive to pay (absent repeated-game incentives). Thus, if the auction process does not reveal the winning bidder ID, a cartel at a second-price auction must rely on correlated equilibria with no transfers among ring members.

Proposition 6 At a second-price auction, if a cartel cannot collect payments from ring members, the first-best collusive outcome cannot be achieved.

Proof. In order to achieve the first-best collusive outcome, non-highest-valuing ring members must bid below the reserve price or not bid. Suppose the existence of an incentive compatible mechanism that recommends that non-highest-valuing ring members bid below the reserve price, and suppose no transfers. Given this mechanism, a ring member with a value above the reserve price strictly prefers to report the maximum possible value rather than truthfully report its value, and then bid its value at the auction. In this case, if the deviating ring member’s value is greater than the values of the outside bidders but less than the value of the highest-valuing other ring member, then the deviation is profitable, and in all other cases, the deviation has no effect on the ring member’s payoff. Q.E.D.

Proposition 6 provides a contrast with Proposition 2, which says the first-best collusive outcome can be achieved when the auctioneer reveals winning bidder ID, and implies that at a second-price auction, if a cartel can only collect payments from a ring member that wins the auction, then an auctioneer can reduce the profitability of collusion by not revealing the winning bidder ID.

When a cartel cannot collect payments from ring members, Proposition 6 implies that the first-best collusive outcome cannot be achieved, but it may still be possible for the ring members to profit from collusion. Without the ability to arrange transfer
payments, the center can only play the role of a correlating device, but as we now show, this can be sufficient to achieve a collusive gain.

In what follows we explore the extent to which collusive gains are possible in the absence of transfers by presenting two examples in which collusive gains are possible at a second-price auction even without transfer payments.

Consider a second-price auction with homogeneous bidders and \( n = k = 2 \) so that there is an all-inclusive ring with two bidders. The bidders can increase their expected payoffs above non-cooperative play using a correlating device that randomly (with equal probabilities) assigns one of the ring members to bid zero and the other to bid the upper support of the value distribution. Ring members need not make reports, and it is incentive compatible for ring members to bid according to the recommendations of the center.

Under this correlating device, expected bidder surplus is

\[
R_v = \int_0^v v dF(v) = \int_0^v (1 - F(v)) dv,
\]

but expected bidder surplus in the non-cooperative equilibrium (in non-weakly dominated strategies) of the second-price auction is

\[
R_v = \int_0^v F(v) (1 - F(v)) dv,
\]

which is strictly less.

Furthermore, under the correlating device, a bidder with value \( v \) has expected surplus \( \frac{1}{2} v \), but under non-cooperative play, a bidder with value \( v \) has expected surplus

\[
\int_0^v (v - b) dF(b) = \int_0^v F(b) db.
\]

If \( \frac{1}{2} v > \int_0^v F(b) db \) for all \( v > 0 \), as with the uniform distribution, bidders with positive values strictly prefer participation in the correlating device even at the interim stage when they know their values.

The outcome under this correlating device is inefficient. In some environments, other correlating devices can be used to reduce the inefficiency and increase expected bidder surplus. For example, with \( n = k = 2 \) if \( v_i \in \{1, 4, 7\} \), with equal probability on each value, and if bids are restricted to the integers \( \{0, 1, 2, ..., 7\} \), then the correlating device that randomly assigns one bidder to bid zero and the other to bid 7 generates expected bidder surplus of 4, expected revenue of zero, and total surplus of 4. But under an optimal correlating device (the optimal correlating device need not be unique), expected bidder surplus is higher and expected revenue is higher.\(^{26}\)

The values for expected bidder surplus, expected revenue, and expected total surplus are given in Table 3. The increase in both expected bidder surplus and expected revenue is possible because the optimal correlated equilibrium does better than the fully

\(^{26}\) An optimal correlating device, which can be calculated using linear programming techniques, is described by \( \Pr(b_1, b_2 \mid r_1, r_2) \) defined as follows:
random correlating device in terms of efficiency, and both bidders and the auctioneer capture some of that efficiency gain.

Table 3: Results for example with two bidders, all-inclusive cartel with no transfers, \( v_i \in \{1, 4, 7\} \), and feasible bids \( \{0, 1, 2, ..., 7\} \)

<table>
<thead>
<tr>
<th></th>
<th>expected bidder surplus</th>
<th>expected revenue</th>
<th>expected total surplus</th>
</tr>
</thead>
<tbody>
<tr>
<td>non-cooperative</td>
<td>2.6667</td>
<td>2.6667</td>
<td>5.3333</td>
</tr>
<tr>
<td>random 0 or 7 correlating device</td>
<td>4</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>optimal correlating device</td>
<td>4.3333</td>
<td>0.6667</td>
<td>5</td>
</tr>
</tbody>
</table>

As shown in Table 3, the expected total surplus from the optimal correlating device remains below that of the non-cooperative outcome, which is efficient, but it is higher than that of the correlating device that randomly assigns bidders to bid either zero or seven. The bidders increase their expected surplus by using the optimal correlating device rather than the correlating device that randomly assigns bidders to bid either zero or seven.

6.2 Mechanisms with resale

The results above assume no resale. Thus, for results predicated on the ring being unable to collect payments from a ring members unless that ring member wins the

| \( r_1 \) | \( r_2 \) | \( b_1 \) | \( b_2 \) | \( \Pr(b_1, b_2 | r_1, r_2) \) |
|----------|----------|----------|----------|-----------------|
| 1        | 1        | 0        | 7        | 0.5             |
| 1        | 1        | 7        | 0        | 0.5             |
| 1        | 4        | 0        | 1        | 0.5             |
| 1        | 4        | 1        | 7        | 0.5             |
| 1        | 7        | 0        | 2        | 0.5             |
| 1        | 7        | 1        | 7        | 0.5             |
| 4        | 1        | 1        | 0        | 0.5             |
| 4        | 1        | 7        | 1        | 0.5             |
| 4        | 4        | 1        | 7        | 0.5             |
| 4        | 4        | 7        | 1        | 0.5             |
| 4        | 7        | 1        | 7        | 0.5             |
| 4        | 7        | 1        | 7        | 0.5             |
| 7        | 1        | 7        | 1        | 0.5             |
| 7        | 4        | 1        | 7        | 0.5             |
| 7        | 4        | 7        | 1        | 0.5             |
| 7        | 7        | 1        | 7        | 0.5             |
| 7        | 7        | 7        | 1        | 0.5             |

One can check that this mechanism is incentive compatible both in terms of truthful reporting to the mechanism and following the bid recommendation of the mechanism.
auction, achieving the first-best collusive outcome requires that the highest-valuing ring member actively bid at the auction. The highest-valuing ring member must bid its value at a second-price auction or remain active up to its value at an ascending-bid auction. We show in Proposition 3 that with non-transparent registration, the first-best collusive outcome cannot be achieved because the highest-valuing ring member has an incentive to register multiple times and use a bidder ID not recognized by the cartel to bid at the auction, thereby avoiding having to make a payment to the cartel.

We can relax our restriction that cartel can only collect payments from a ring member that wins the auction to say instead that the cartel can only collect payments from a ring member that receives that object. Then the first-best collusive outcome could still be achieved if a bidder other than the highest-valuing ring member bid at the auction, as long as the collusive mechanism ultimately allocated the object to the highest-valuing ring member. In this case, the possibility of first-best collusion is restored if the ring has access to a disinterested party that can be used to submit a bid equal to the value of the highest-valuing ring member. In this case, the result of Proposition 3 is reversed. Instead, the first-best can be achieved. Specifically, the ring can use the mechanism of Graham and Marshall (1987) with the modification that the highest-reporting ring member is told not to bid, and instead the disinterested party is told to bid an amount equal to the report of the highest-reporting ring member. Then the object is transferred to the highest-reporting ring member at a resale price equal to the purchase price at the auction, and the highest-reporting ring member makes transfer payments as defined in Graham and Marshall (1987).

Of course, this type of mechanism is vulnerable to collusion between the highest-valuing ring member and the party bidding for the cartel at the auction. Furthermore, if the disinterested party is not truly disinterested, the mechanism is vulnerable to the use of a disguised bidder ID by that party.

7 Discussion

Many results in the auction literature that hold for second-price auctions also hold for ascending-bid auctions, and vice versa. However, the results of this paper show that this is not always the case. A cartel operating at an ascending-bid auction need not be disrupted by non-transparent registration; however, we show that under certain conditions non-transparent registration forces a cartel at a second-price auction to
revert to non-collusive play. This shows that there is a difference between ascending-bid and second-price auctions insofar as their susceptibility to collusion.

A cartel at a second-price auction with non-transparent registration can successfully collude if it abandons mechanisms that only require payments from the winner and opts for a more general mechanism, such as that described prior to Proposition 1. But, this mechanism requires payments from all bidders, including losing bidders. Losing bidders are likely to resist a mechanism that requires payments from them.\(^{27}\)

The results of this paper suggest that both the design of an auction and the actions of auctioneers can affect the profitability of collusion. Auction designs and auctioneer actions that reduce the profitability of collusion can be expected to inhibit collusion. Prior to an auction, steps can be taken to facilitate the use of disguised identities by potential cartel members, such as using non-transparent registration. During ascending-bid auctions, information on the identities of the active bidders and the current high bidder can be suppressed. After an auction, if possible, the auctioneer can keep the identity of the winner anonymous. Also after an auction, bid data can be reviewed for evidence of simultaneous exit that might be suggestive of cartel behavior.

“Transparency in bidding” has been touted by the federal government. As described in the Introduction, in certain applications increased information disclosure can increase efficiency, particularly in environments with externalities. However, certain kinds of transparency can facilitate collusion. As we show in this paper, pre-auction transparency in the form of transparent registration, and real-time transparency in the form of revelation of the identities of the active bidders in a JEA and the identity of the current high bidder in an SEA, increase susceptibility to collusion. Thus, pre-auction and real-time transparency are pro-collusive. If the motivation for “transparency in bidding” is concern about the possibility of corruption, then post-auction transparency, where auction results are made public after the conclusion of the auction, may provide sufficient information to monitor the auction process without being as pro-collusive as pre-auction or real-time transparency.

Additional benefits associated with suppressing information on the identities of active bidders and current high bidders are possible in simultaneous multiple object...

\(^{27}\)Individual budget constraints and risk aversion are two potential obstructions to the use of the collusive mechanism described prior to Proposition 1 relative to a mechanism in which only the winner pays.
auctions. For example, in the FCC’s spectrum license auctions information on the identities of bidders can potentially facilitate retaliatory bidding, signalling, gaming of the auction’s activity rule, and other attempts to deter or foreclose entry into markets (see, e.g., Brusco and Lopomo, 2002; Marx, 2006; and Reitsma et al., 2002). Recently the FCC announced that in some cases it would modify its simultaneous multiple round auction (a multi-object variant of an English auction) so that bidders could no longer observe which bidder had submitted which bids. The FCC argued that this change would make its auctions less susceptible to collusion, a conclusion that is supported by the analysis of this paper.
A Appendix – Russian oil and gas auctions

We have data for 620 auctions from 2004 to 2007. For 121 auctions the data are complete, but for 499 auctions there is only partial information available currently. Most of our focus will be on the 121 auctions for which the data are complete. On average, these auctions are slightly larger than those in the remainder of the data in the sense that the average reserve price for the 121 leases where the data are complete is 71,503,769 rubles, and the average reserve price for the remaining 499 where the data are not complete is 49,484,900 rubles.

Table A.1 focuses on the 121 where the data are complete and shows the distribution of auctions by number of participants and winning bids (in terms of the number of bid increments above the reserve price). As the table shows, 20% of the auctions involved two bidders where only one bidder bid and won the object at the lowest feasible price of one bid increment above the reserve price. Also shown in the table, for auctions with six or more participants the winning bid is always 20 or more increments above the reserve price, but for auctions with five or fewer participants there is at least one auction for which the winning bid was only one increment above the reserve price, which is the lowest feasible bid.

Table A.1: Winning bids and number of participants for the sample of 121 auctions for which the data are complete

<table>
<thead>
<tr>
<th>Participants</th>
<th>$Z = 1$</th>
<th>$Z = 2$</th>
<th>$Z = {3, \ldots, 19}$</th>
<th>$Z = {20, \ldots, 99}$</th>
<th>$Z \geq 100$</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>0.20</td>
<td>0.10</td>
<td>0.03</td>
<td>0.03</td>
<td>0.02</td>
<td>0.37</td>
</tr>
<tr>
<td>3</td>
<td>0.01</td>
<td>0.03</td>
<td>0.08</td>
<td>0.12</td>
<td>0.06</td>
<td>0.30</td>
</tr>
<tr>
<td>4</td>
<td>0.01</td>
<td>0.00</td>
<td>0.02</td>
<td>0.02</td>
<td>0.07</td>
<td>0.11</td>
</tr>
<tr>
<td>5</td>
<td>0.01</td>
<td>0.01</td>
<td>0.02</td>
<td>0.01</td>
<td>0.04</td>
<td>0.09</td>
</tr>
<tr>
<td>6</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.01</td>
<td>0.03</td>
<td>0.03</td>
</tr>
<tr>
<td>7</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.01</td>
<td>0.01</td>
<td>0.02</td>
</tr>
<tr>
<td>8</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.01</td>
<td>0.00</td>
<td>0.01</td>
</tr>
<tr>
<td>9</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.01</td>
<td>0.03</td>
<td>0.03</td>
</tr>
<tr>
<td>10</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.01</td>
<td>0.01</td>
<td>0.02</td>
</tr>
<tr>
<td>11</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.02</td>
<td>0.02</td>
</tr>
<tr>
<td>Total</td>
<td>0.23</td>
<td>0.13</td>
<td>0.15</td>
<td>0.22</td>
<td>0.28</td>
<td>1.00</td>
</tr>
</tbody>
</table>

Table A.2 shows the data in slightly different form by conditioning the distributions on the number the participants in the auctions. The table clearly shows differences in the distribution of winning bids between auctions with two bidders, auctions with three to five bidders, and auctions with six or more bidders.

\footnote{The data are available on the website for the Center for the Study of Auctions, Procurements and Competition Policy at Penn State: http://econ.la.psu.edu/CAPCP/}
Table A.2: Proportion of auctions with winning bids of varying numbers of bid increments above the reserve price conditional on number of participants for the sample of 121 auctions for which the data are complete

<table>
<thead>
<tr>
<th>Number of participants</th>
<th>Number of bid increments that the winning bid is above the reserve price</th>
<th>Number of auctions</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>53% 26% 9% 7% 5% 100% 45</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>3% 9% 26% 41% 21% 100% 36</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>8% 0% 15% 15% 62% 100% 14</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>10% 10% 20% 10% 50% 100% 11</td>
<td></td>
</tr>
<tr>
<td>6 or more</td>
<td>0% 0% 0% 33% 67% 100% 16</td>
<td></td>
</tr>
<tr>
<td>Combined</td>
<td>23% 13% 15% 22% 28% 100% 121</td>
<td></td>
</tr>
</tbody>
</table>

Examining further the data on 121 auctions for which the data are complete, there are 42 two-bidder auctions. In 34 of these 42 two-bidder auctions (81%), the winning bid is only one or two bid increments above the reserve price. One possible explanation for the apparently low interest in these auction is that they may be small licenses of interest only to regional bidders. In fact, the average reserve price for this sample of 34 two-bidder auctions with winning bids that are one or two bid increments above the reserve price is 27,515,294 rubles, which is less than half the average reserve price for the full set of 620 auctions.

If only a single bidder registers for an auction, then the auction is not held. So if a license is only of interest to a single bidder, then that bidder may have an incentive to arrange for a second bidder to register but not compete at the auction. In fact, our data is suggestive of this type of behavior. To see this, focus on the 34 two-bidder auctions with winning bids that are one or two bid increments above the reserve price. For these auctions, we assign identifying letters to each of the participants (bidder names are often long and are in Russian). See the last table of this appendix for the details of these assignments.

As shown in Table A.3, there are 24 distinct winning bidders and 26 distinct losing bidders. There are 26 distinct ordered pairs of winning and losing bidders. Also shown in the table, it is often the case that the losing bidder never wins any auctions in our sample of 620 auctions. For example, bidder Y won 6 two-bidder auctions with a winning bid of one or two bid increments above the reserve price, and in all six of these auctions, bidder Y’s opponent was bidder 1Y. Bidder 1Y never won any of the auctions for which we have data. Also shown in the table, bidders 1L and 1N show up as both winning and losing bidders—bidder 1L won an auction with 1N as the losing bidder, and bidder 1N won an auction with bidder 1L as the losing bidder (bidder 1L also won an auction with bidding 1M as the losing bidder).
Table A.3: Bidder identities for the sample of 34 two-bidder auctions for which data are complete and the winning bid is one or two bid increments above the reserve price

<table>
<thead>
<tr>
<th>Winner</th>
<th>Loser</th>
<th>Number of auctions</th>
<th>Other auctions in our sample of 620 auctions won by the second-place bidder</th>
</tr>
</thead>
<tbody>
<tr>
<td>1B</td>
<td>1C</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>1D</td>
<td>1E</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1F</td>
<td>1G</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1H</td>
<td>1I</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>1J</td>
<td>1K</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>1L</td>
<td>1M</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>1L</td>
<td>1N</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1N</td>
<td>1L</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>1O</td>
<td>1P</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1Q</td>
<td>1R</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>1S</td>
<td>1T</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>1U</td>
<td>1V</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>A</td>
<td>B</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>D</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>F</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>G</td>
<td>H</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>J</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>K</td>
<td>L</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>N</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>M</td>
<td>Q</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>O</td>
<td>P</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>R</td>
<td>S</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>T</td>
<td>U</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>V</td>
<td>X</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Y</td>
<td>1Y</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Z</td>
<td>1A</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>34</td>
<td>11</td>
</tr>
</tbody>
</table>

This data suggest that some of the losing bidders may not have been competitive bidders. We use the data to classify the 26 distinct losing bidders in the 34 two-bidder auctions with a winning bid of one or two bid increments above the reserve price as “pure shills,” “occasional shills,” or “rotating bidders” as follows:

We classify 13 of the losing bidders, B, D, H, L, P, X, 1Y, 1A, 1C, 1I, 1K, 1R, and 1T, as “pure shills” because:

1. the losing bidder either did not bid or bid only once (the object was sold at one or two bid increments above the reserve price),

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2. the losing bidder never won a lease at any of the 620 auctions for which we have data, and

3. the losing bidder did not participate in any auction in the absence of the winning bidder.

We classify 2 of the losing bidders, 1L and 1N, as “rotating bidders” because as a pair, the two bidders participated in multiple two-bidder auctions, with each bidder winning at least one auction at a price only one or two bid increments above the reserve price.

Finally, we classify the remaining 11 losing bidders, F, J, N, Q, S, U, 1E, 1G, 1M, 1P, and 1V, as “occasional shills.” These bidders either did not bid or bid only one time, allowing the other bidder to win the item at a price one or two bid increments above the reserve price. But these bidders either won auctions in our sample of 620 auctions (bidder 1G), or participated in auctions without their partner (bidder U), or both (bidders F, J, N, Q, S, 1E, 1M, 1P, 1V).

Particularly in the cases of pure shills, one might suspect that these losing bidders were merely shills for the winning bidder, attending the auction to fulfill the requirement that there be at least two bidders at the auction.

Our model allows for different registration regimes, including the possibility for bidders to register multiple times. Thus, our model allows the creation of shill bidders as appears to have happened in the Russian oil and gas lease auctions.

Because we would classify the Russian oil and gas lease auctions as semi-transparent (the list of bidder IDs is revealed prior to the auction), our results, particularly Proposition 5, suggest that there is no role for shills in a well-functioning cartel. However, if we consider the 13 “pure shills” identified in the Russian oil and gas data, we find that two of these pure shills, L and X, participated with their partners (the winning bidders) in auctions with more than two bidders.29 Our model is not dynamic, so perhaps dynamic considerations create a role for shill bidding. For example, the partners might use these other auctions to try to establish the credibility of their shills as bidders. Our model also assumes a non-strategic auctioneer (except for setting a fixed reserve price), but perhaps with a strategic auctioneer there is a role for shills to disguise the presence of a cartel or limit the auctioneer’s ability to behave strategically (e.g., by using a “quick knock” to try to allocate the item to a non-cartel bidder). Finally, our model assumes that the number and identities of the cartel bidders are common knowledge within the cartel. If this were not the case, a cartel member might have an incentive to develop a shill and enter that shill into the cartel in order

Bidder L and its partner, bidder K, participated in a three-bidder auction, which K won (5 bid increments) and a four-bidder auction, which neither K nor L won (320 increments). Bidder X and its partner, bidder V, participated in a four-bidder auction, which V won (12 increments). Bidder B participated in another two-bidder auction with its partner, bidder A. The number of bid increments in this auction is not known. None of the other pure shills participated in any auctions outside the 34 auctions on which we have focused.

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to capture an additional share of the collusive gain. We leave for future research a more detailed exploration of the various roles for shill bidders.

Table A.4: Assignment of identifying letters to bidders in Russian oil and gas lease auctions with two participants and a winning bid of one or two bid increments above the reserve price

<table>
<thead>
<tr>
<th>Participant Company</th>
<th>Company Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>ООО &quot;РосНедра Астрахань&quot;</td>
</tr>
<tr>
<td>B</td>
<td>ООО &quot;ВолжСторНЭСТ&quot;</td>
</tr>
<tr>
<td>C</td>
<td>ЗАО &quot;Нефтегазовая компания АФБ&quot;</td>
</tr>
<tr>
<td>D</td>
<td>ЗАО &quot;Концерн &quot;Нефтепродукт&quot;</td>
</tr>
<tr>
<td>E</td>
<td>ООО &quot;Интенсификация и повышение нефтеотдачи пласта&quot;</td>
</tr>
<tr>
<td>F</td>
<td>ООО &quot;ЗАAB Инвест&quot;</td>
</tr>
<tr>
<td>G</td>
<td>ЗАО &quot;Фроловское нефтегазодобывающее управление&quot;</td>
</tr>
<tr>
<td>H</td>
<td>ЗАО &quot;Вольновскнефть&quot;</td>
</tr>
<tr>
<td>I</td>
<td>ЗАО &quot;Транс Нафта&quot;</td>
</tr>
<tr>
<td>J</td>
<td>ООО &quot;Газнефтехсервис&quot;</td>
</tr>
<tr>
<td>K</td>
<td>ООО &quot;Авангард&quot;</td>
</tr>
<tr>
<td>L</td>
<td>ООО &quot;Истенойл&quot;</td>
</tr>
<tr>
<td>M</td>
<td>ООО &quot;Новосибирскнефтягас&quot;</td>
</tr>
<tr>
<td>N</td>
<td>ООО &quot;Тагульское&quot;</td>
</tr>
<tr>
<td>O</td>
<td>ООО «Северное сияние»</td>
</tr>
<tr>
<td>P</td>
<td>ООО &quot;Гранит&quot;</td>
</tr>
<tr>
<td>Q</td>
<td>ООО &quot;Северное сияние&quot;</td>
</tr>
<tr>
<td>R</td>
<td>ООО ПКФ «Селена»</td>
</tr>
<tr>
<td>S</td>
<td>ООО &quot;ЛДМ&quot;</td>
</tr>
<tr>
<td>T</td>
<td>ООО «Пермоблнефть»</td>
</tr>
<tr>
<td>U</td>
<td>ООО ПКФ &quot;Центртехнаб&quot;</td>
</tr>
<tr>
<td>V</td>
<td>ООО «Парма-Ресурс»</td>
</tr>
<tr>
<td>W</td>
<td>ООО &quot;Проминвест&quot;</td>
</tr>
<tr>
<td>X</td>
<td>ООО &quot;АНК Башнефть&quot;</td>
</tr>
<tr>
<td>Y</td>
<td>ООО &quot;Башминерал&quot;</td>
</tr>
<tr>
<td>Z</td>
<td>ООО &quot;ДНК&quot;</td>
</tr>
<tr>
<td>1A</td>
<td>ООО &quot;Калинковиль ЛТД&quot;</td>
</tr>
<tr>
<td>1B</td>
<td>ООО &quot;Ингушинефтегазпром&quot;</td>
</tr>
<tr>
<td>1C</td>
<td>ООО &quot;НПЦ Ингушроссгео&quot;</td>
</tr>
<tr>
<td>1D</td>
<td>ООО &quot;Холмогорнефтегаз&quot;</td>
</tr>
<tr>
<td>1E</td>
<td>ООО &quot;Самотлорнефтегаз&quot;</td>
</tr>
<tr>
<td>1F</td>
<td>ООО &quot;Сахалин-Девелопмент&quot;</td>
</tr>
<tr>
<td>1G</td>
<td>ООО &quot;Томгаснефть&quot;</td>
</tr>
<tr>
<td>1H</td>
<td>ООО &quot;Уралинвест&quot;</td>
</tr>
<tr>
<td>1I</td>
<td>ООО &quot;Уралтрансгаз&quot;</td>
</tr>
<tr>
<td>1J</td>
<td>ООО &quot;Батайскнефтегаз&quot;</td>
</tr>
<tr>
<td>1K</td>
<td>ООО &quot;Аксайнефтегаз&quot;</td>
</tr>
<tr>
<td>1L</td>
<td>ООО &quot;Славуптич&quot;</td>
</tr>
<tr>
<td>1M</td>
<td>ООО &quot;Союзнефтестрой&quot;</td>
</tr>
<tr>
<td>1N</td>
<td>ООО &quot;ФУТЭК&quot;</td>
</tr>
<tr>
<td>1O</td>
<td>ООО &quot;Негуснефть&quot;</td>
</tr>
<tr>
<td>1P</td>
<td>ООО &quot;Ульяновскнефть&quot;</td>
</tr>
<tr>
<td>1Q</td>
<td>ООО &quot;Холдинговая компания Сигма-групп&quot;</td>
</tr>
<tr>
<td>1R</td>
<td>ООО &quot;Инвестиционная группа АЛРОСА&quot;</td>
</tr>
<tr>
<td>1S</td>
<td>ООО &quot;Звенигородская теплоэнергетическая компания&quot;</td>
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<td>1T</td>
<td>ООО &quot;Горно-промышленная компания &quot;Самсон&quot;</td>
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<td>ООО &quot;НК &quot;Мангазей&quot;</td>
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<td>ООО &quot;Сибнефть-Новосибирскнефтягас&quot;</td>
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B Appendix – Collusive mechanisms

In this appendix, we define a collusive mechanism for a second-price auction when no registration-related information is revealed. The definition can be adapted for other auction formats and registration regimes.

We focus on incentive compatible, ex-ante budget balanced, strictly individually rational collusive mechanisms.

Assume bidder $i$ draws its values from distribution $F_i$ with interval support $S$, where $S$ is common to all bidders.

Let $K \equiv \{1, \ldots, k\}$. To allow the possibility that cartel members can submit multiple bids, for $i \in K$, let cartel member $i$’s bid $b_i$ be a finite-dimensional vector. If the mechanism recommends that cartel member $i$ submit bid vector $b_i$ with dimension $m_i$, we interpret that as a recommendation that cartel member $i$ should register $m_i$ bidders with itself as the underlying identity and submit bids accordingly. Let $B$ be the set of possible vectors of bid recommendations. For $i \in K$, let $\pi_i(v_i, b_1, \ldots, b_k)$ be cartel member $i$’s expected payoff when its value is $v_i$, cartel members bid $b_1, \ldots, b_k$, and outside bidders bid their values, taking the expectation over the outside bidders’ values (and the number of outside bidders if that is not known) and over any randomization in the auction mechanism, such as a random tie-breaking rule.

We define a collusive mechanism by $(\mu, p)$, where $\mu : S^k \rightarrow \Delta(B)$ is the distribution over recommended bids and $p_i : S^k \times I \rightarrow \mathbb{R}$ is the transfer payment required of cartel member $i$ as a function of the reports made to the cartel center and the information $I$ revealed as part of the auction process. It will also be useful to define the associated expected transfer payment for cartel member $i$ given its report $\tilde{p}_i : \mathbb{R} \rightarrow \mathbb{R}$. A collusive mechanism $(\mu, p)$ is incentive compatible if $\forall i \in K$, $\forall (v_i, v_i') \in S^2$, $\forall \psi_i : B_i \rightarrow B_i$,

$$E_{v_i \sim \mu} \left( \int_B \pi_i(v_i, b_i, b_{-i}) d\mu(b_1, \ldots, b_k \mid v_i, v_{-i}) \right) - \tilde{p}_i(v_i) \geq E_{v_i \sim \mu} \left( \int_B \pi_i(v_i, \psi_i(b_i), b_{-i}) d\mu(b_1, \ldots, b_k \mid v_i', v_{-i}) \right) - \tilde{p}_i(v_i').$$

Condition (1) captures two types of incentive compatibility constraints. It ensures that cartel members report truthfully to the mechanism, and it also ensures that cartel members follow the recommendation of the center when they register and bid at the auction. (We interpret a $\psi_i$ that maps an $m_i$-dimensional bid recommendation onto a bid vector with different dimension as capturing a deviation by the cartel member in the number of bidders it registers with itself as the underlying identity.) Cartel members use the information contained in their recommendation to update their beliefs about the recommendations made to the other cartel members and to determine their optimal registration and bidding behavior. In an incentive compatible mechanism, it is optimal for cartel members to obey the recommendation of the center given their posterior beliefs.

The mechanism is ex-ante budget balanced if $E_{v_1, \ldots, v_k} \left( \sum_{i \in K} \tilde{p}_i(v_i) \right) = 0$, and
participation in $\mu$ is strictly individually rational if $\forall i \in K$,

$$E_{v_e} \left( \int_B \pi_i(v, b_i, b_{-i}) d\mu(b_1, \ldots, b_k | v_i, v_{-i}) - \hat{p}_i(v_i) \right)$$

is greater than cartel member $i$'s ex-ante expected payoff when all bidders play non-cooperatively.

References


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