Abstract

Previous work has taken the rules and environments of auctions as given and assessed the relative vulnerability of different schemes as the collusive mechanism changes. In this paper, we take the collusive mechanism as fixed and ask how different rules and environments differentially impact the vulnerability of auction schemes to collusion. Ascending-bid auctions can be more or less susceptible to bidder collusion than second-price auctions depending on the rules and environments. Rules and environments that are of no consequence for non-cooperative conduct can be important for the viability of collusion by bidders.
1 Introduction

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. Definitions are often offered for each. However, the definitions 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 it suffices to say that a second-price auction is a sealed-bid auction where the high bidder wins and pays the amount of the second-highest bid, a first-price auction is a sealed-bid auction where the high bidder wins and pays the amount of their bid, a Dutch auction is a descending-bid auction where the first bidder to stop the descent wins and pays the price at which they stopped the descent, and an ascending-bid auction is one where the bidding ascends until the moment when only one bidder remains active and then that sole remaining bidder wins for the price at which the ascent stopped. Nothing is typically specified about pre-registration by bidders or whether bidders can submit more than one bid, to name just two common omissions. 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 specific to the ascending-bid auction. 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.\footnote{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.} However, as we show, many of the omitted components of the definition of an auction are not inconsequential when one relaxes these basic assumptions.\footnote{See Izmalkov (2002) on English auctions with reentry and see Avery (2002) on strategic jump bidding at English auctions.} In this paper, we relax the assumption of non-cooperative bidders and consider the effects of auction environments on the ability of bidders to collude.

Our focus is on collusive bidding by a ring that is less than all-inclusive. Such a cartel has some basic concerns for conducting their affairs. The collusive 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. The study of bidding rings requires greater specificity regarding the definition of the auction because aspects of an auction that are inconsequential for non-cooperative behavior may be material when bidders collude. As one motivating case, 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 their 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, this kind of communication occurred at the FCC’s PCS A & B Block Spectrum Auction (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 “non-collusive” assumption is relaxed, such details become a critical part of the definition of the ascending-bid auction.

In the economics literature on auctions, it is common to treat ascending-bid auctions and second-price auctions as equivalent. In fact, Vickrey (1961) argued that the two auction formats are strategically equivalent (“logically isomorphic” in Vickrey’s language). The economics literature views ascending-bid and second-price auctions as susceptible to bidder collusion, and for the same reasons. At a second-price auc-

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3For other papers discussing the susceptibility of FCC auctions to collusion, see Brusco and Lopomo (2002), Cramton and Schwartz (2000, 2002), Kwasnica and Sherstyuk (2001), and McAfee and McMillan (1996).

4See Weber (1997).

5The 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).

6See the intuition provided in Marshall and Meurer (2004).
tion, a ring has its highest-valuing member bid its value while all other ring members bid zero or some amount below the auctioneer’s reserve price. Similarly, this same ring at an ascending-bid auction could have its highest-valuing member remain active up to its value and prevent the other ring members from meaningfully opposing that bidder. In each case, the highest-valuing ring member acts just as it would have had the bidding been non-cooperative, and thus there is no incentive for any other ring member to deviate from the agreement.

Despite the view that opportunities for collusion may be similar in the two auction formats,\(^7\) in this paper we show that ascending-bid and second-price auctions can differ in terms of their susceptibility to collusion in certain environments and with certain auction rules. For example, consider collusive mechanisms similar to that of Graham and Marshall (1987) that are based on pre-auction communication and that only collect payments from a ring member if that ring member wins the auction. The environment and rules of the second-price and ascending-bid auctions can create differential opportunities for deviant behavior by ring members. We show for specific rules and environments, when within-cartel payments can only be required from a ring member who wins the auction, the ability of ring members to submit multiple bids need not affect the profitability of a ring at an ascending-bid auction, but it can prevent a ring at a second-price auction from being able to suppress all ring competition. But, for different rules and environments, the converse can be true. Thus, our results suggest that ascending-bid auctions can be more susceptible to collusion than second-price auctions, or less susceptible, depending on the specifics of the auction rules and environment.

The paper proceeds as follows. The specifics of rules and environments that are often left unspecified with non-cooperative play but which are potentially consequential for collusion are enumerated and discussed in Section 2, along with the details of our modeling framework. Results are in Section 3, including implications of our findings for collusion deterrence. Section 4 concludes.

\(^7\) 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.”
2 Model

We are interested in bidding rings that operate in single object auction environments, where the bidding is in terms of the price only. We consider a variety of auction formats, the rules that define them, the environments within which bidders function, as well as different cartel organizations.

2.1 Auction formats

2.1.1 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 its bid. 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.

In both of these auction formats, for the purposes of studying collusion, we must also specify what information is available to the bidders, including possibly: the number and/or identities of the eligible bidders if bidders must register and/or qualify to bid, the number and/or identities of the actual bidders, the price paid, the identity of the winner, and the bids, either with or without the identities of the associated bidders, and allowing for the possibility of more than one bid per bidder.

A first-price or second-price auction concludes with the revelation by the auctioneer of at least the following information: the winning bidder is notified that they won, the winning bidder is notified of the price they must pay for the object, and losing bidders are notified that they did not win. In what follows, to maintain comparability between sealed-bid and ascending-bid auctions, where the price paid is revealed by the auction process, we assume that the price paid is revealed at sealed-bid auctions as well.

2.1.2 Ascending-bid auctions

A variety of ascending-bid environments are used in practice and in theory. 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 withdraws from the bidding they cannot reenter. In addition, the number of active bidders, and thus the exit point of bidders, is publicly displayed, but the identities of the active
bidders are not revealed during the auction. 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 identities 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 is also common for bidders to be able to observe the identity 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 identity 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, there is an attempt to disguise the identities of the active bidders and current high bidder 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. As with the sealed-bid auction formats, 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. Other information that may or may not be revealed includes: the number and/or identities of the eligible bidders if bidders must register and/or qualify to bid, the number and/or identities of the actual bidders, the identity of the winner, the identities of the currently active bidders for a JEA, identity of the current high bidder for an SEA, and allowing for the possibility of more than one bid per bidder. In addition, for studying collusion at ascending-bid auctions it may also be important to specify how bid increments are determined. The bid increments could be discrete or the bidding could ascend continuously. The rate of the ascent could vary with the number of active bidders. The increments could be under the control of the auctioneer or the auctioneer may allow bidders to call out their own bids.
2.1.3 Other auction details

For all the auction formats described above, the profitability of collusion also may be affected by the following features: whether pre-registered joint bidding is allowed; whether resale after the auction is allowed or whether joint ownership is allowed; payment terms and default rules; whether information about the item known by auctioneer and/or owner is revealed prior to the auction; the reserve price policy; whether a starting bid is announced prior to the auction; whether the owner of the item is a bidder, and whether the owner’s identity is revealed.

For each of these auction features, it remains an open question whether changes in the features has a differential impact between auction schemes in terms of their relative susceptibility to collusion. For example, the pre-registration and public announcement of all potential bidders may increase the prospects for successful collusion at sealed-bid auctions (both second and first price), whereas this may have no impact on the susceptibility of ascending-bid auctions where bidder identities are observable during the auction.

The “classic” ascending-bid auction typically involves the following: there is no restriction on reentry, pre-auction registration occurs but with potential bidders not publicly identified or numbers announced, a subset of the active bidders is observed during the auction, the total number of active bidders are not observed, bid increments are discrete, the auctioneer has a reserve price but does not announce it, the auctioneer is not the owner of the object, the owner cannot bid at the auction, the information known by the auctioneer and/or owner about the item is announced before bidding, the winner pays in-full immediately after the conclusion of the auction, no joint bidding is allowed, and resale is permitted.

2.2 Notation and timing

We focus on the case of a single-object auction with a non-strategic auctioneer. We use the heterogeneous IPV model, which is important for the study of collusion because, even if bidders are homogeneous, collusion creates heterogeneity among them. Bidding behavior and expected revenue within a heterogeneous IPV framework has been analyzed by Bajari (2001), Lebrun (1999, 2006), Marshall et al. (1994), as well as Maskin and Riley (2000). We assume bidder \( i \) draws its values from distributions \( F_i \) with support \( S_i \), which we assume is an interval with lower support equal to zero.
We assume there are $n \geq 2$ actual bidders (as opposed to the number of registered bidders, which may be higher), and $k$ of those bidders are eligible to participate in a ring, where $2 \leq k \leq n$. We assume that the identities of the $k$ ring bidders are common knowledge within the ring, but that the total number of bidders is not known unless announced by the auctioneer or revealed through the registration or auction process. We use indices $1, \ldots, k$ to denote ring members and $k+1, \ldots, n$ to denote outside bidders. We let $N \equiv \{1, \ldots, n\}$ denote the set of all bidders, $K \equiv \{1, \ldots, k\}$ denote the set of ring bidders and $\Omega \equiv \{k+1, \ldots, n\}$ denote the set of outside bidders. We assume that outside bidders use the weakly dominant strategy of bidding their values.\footnote{We assume non-colluding bidders follow non-weakly dominated strategies, but ring members are not so constrained. In Graham and Marshall (1987), Mailath and Zemsky (1991), and Robinson (1985), the authors also make this assumption. This is consistent with observed behavior in Finnegans v. Campeau; U.S. v. Seville Industrial Machinery Corp., 696 F.Supp. 986 (D.N.J. 1988); U.S. v. Ronald Pook, No. 87-274, 1988 U.S. Dist. LEXIS 3398 (E.D. Pa. April 18, 1988); and District of Columbia, ex rel. John Payton, Corporation Counsel v. George Basiliko, et al., No. 91-2518, 1992 U.S. Dist. LEXIS 1260 (D.C. February 10, 1992).}

We allow the possibility that the auction rules permit ring bidders to register multiple times and thereby submit multiple bids (our results are not affected if outside bidders are able to do this as well). If a ring bidder registers multiple bidders, we refer to that ring bidder as the underlying identity behind those registered bidders, and we assume the ring bidder controls the bidding of all registered bidders with it as the underlying identity. In practice, multiple registrations by a ring bidder may be accomplished if the ring bidder has formal or informal agreements with another entity, perhaps specifying the terms of resale following success at the auction, and if that entity registers as a bidder.

In what follows, when we say the true identities of the bidders are revealed, we mean that each registered bidder can be traced to the underlying identity behind it. For example, if the auctioneer announces some information about the identity of a bidder, but if the auctioneer does not reveal sufficient information for one of the multiple registrations of a ring bidder to be traced to its underlying identity, then we will describe that auction as one in which identities are not revealed. Similarly, if auction rules prevent ring members from being able to identify registrations by a ring bidder created through formal or informal agreements with other entities, then we describe that auction as one in which identities are not revealed.

The timing is as follows: First, a ring mechanism is announced (there is commit-
ment to the mechanism). Both potential ring members and outside bidders observe the mechanism. Second, potential ring members decide whether to join. We assume they join if and only if their expected payoff from participation in the mechanism is greater than or equal to their expected payoff from non-cooperative play. All bidders observe whether all potential ring members join or not. If all potential ring members join, then the ring mechanism operates and otherwise it does not, in which case all bidders participate in the auction non-cooperatively. Third, bidders learn their values and, if the ring mechanism is operating, ring members participate in the collusive mechanism. Fourth, all bidders participate in the auction mechanism, including registration and possibly the release of registration-related information, and then the bidding process with the associated release of information. We allow auction rules that suppress registration-related information and certain bidding information, but we assume the information cannot be misrepresented. We assume only registered bidders may participate in the bidding process, although we allow the possibility that a ring member could be the underlying identity of multiple registered bidders. Fifth, any within-ring transfer payments required by the mechanism are made. These transfers can be conditioned on any information revealed during or after the auction.

The ring mechanism operates as follows: Each ring member makes a report to a “center,” which is a standard Myerson (1983) incentiveless mechanism agent. Based on these reports, the center makes non-binding registration and bid recommendations to each ring member. A ring member’s recommendations are not observed by the other ring members. After the conclusion of the auction, the mechanism requires transfers among ring members. We assume the ring can compel ring members to make their required payments. We require that the center’s budget be balanced in expectation.

\footnote{We do not need outside bidders to observe the mechanism used by the ring, 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 ring is operating or not, i.e., whether all potential ring members chose to join.}

\footnote{This is a common simplifying assumption in the auction literature. The assumption affects the statement of the individual rationality (IR) constraint, but is not necessary for the results of this paper. An alternative assumption is that refusal by one potential ring member to join the ring implies that the remaining potential ring members form a ring of size \( k - 1 \).
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\footnote{The notion of a center, an incentiveless agent who facilitates implementation of the mechanism, was introduced by Myerson (1983).
}

\footnote{Our model can incorporate the case of no registration simply by assuming that no information related to registration is revealed.
}
We require that, given a particular collusive mechanism, the behavior of the bidders forms a Bayesian-Nash equilibrium. In particular, all bidders take the collusive mechanism as given. Conditional on all ring members choosing to join the ring, each ring member’s strategy is a report to the ring (as a function of its value) and registration and bidding behavior (as a function of its value, the ring’s recommendation, and any available information revealed through the registration and auction process). We require that each bidder’s strategy be a best reply to the other bidders’ strategies given their beliefs about the other bidders, and we require that bidders’ beliefs be consistent with the prior that each bidder $i$’s value is drawn from $F_i$ and Bayesian updating. In the initial stage of the game, ring members choose whether to join or not given their prior beliefs about their own values and the other bidders’ values, and given equilibrium behavior in the later stage of the game.

2.3 First-best collusive outcomes

In the context of a second-price auction, the first-best collusive outcome is achieved when the highest-valuing ring member bids its value and all other ring members bid zero. With an all-inclusive ring, the first-best collusive outcome can also be achieved if the highest-valuing ring member bids some amount greater than zero and all other ring members bid zero. In the context of a JEA, the first-best collusive outcome is achieved when the highest-valuing ring member remains active up to its value and all other ring members exit at a price less than the highest-valuing ring member’s value and at a price no greater than the price at which the highest-valuing outside bidder exits. With an all-inclusive ring, the first-best collusive outcome can also be achieved if the highest-valuing ring member remains active up to some amount above zero and all other ring members exit at zero. In an SEA, the first-best collusive outcome is achieved when non-highest-valuing ring members do not bid when the highest-valuing ring member is the current high bidder and do not bid when an outside bidder is the current high bidder until the highest-valuing ring member has had an opportunity to bid.

2.4 Collusive mechanisms

Following the Revelation Principle, we focus on incentive compatible mechanisms. In what follows we let $v^k$ denote the vector of values for the ring members, i.e.,
\( v^k = (v_1, ..., v_k), \ v^k_i \) denote the values of ring members other than \( i \), and \( v_{-i} \) denote the values of all bidders other than \( i \).

We begin by defining the collusive mechanism for a sealed-bid auction in which no registration-related information is revealed, and then discuss the more complicated definitions for the cases with the revelation of registration-related information and for ascending-bid auctions.

For \( i \in K \), let \( \pi_i(v_i, b_1, ..., b_k) \) be ring member \( i \)'s expected payoff when its value is \( v_i \), ring members bid \( b_1, ..., b_k \), 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. As discussed above, we allow the possibility that ring members can submit multiple bids, so for \( i \in K \), we allow the bid \( b_i \) to be a vector with maximum dimension \( d_i < \infty \). If the mechanism recommends that ring member \( i \) submit bid vector \( b_i \) with dimension \( m_i \leq d_i \), we interpret that as a recommendation that ring member \( i \) should register \( m_i \) bidders with itself as the underlying identity. We let \( B \) be the set of possible vectors of bid recommendations and let \( S_i \) be the set of possible vectors of ring member values.

We define a collusive mechanism by \( (\mu, p) \), where \( \mu : S \to \Delta (B) \) is the distribution over recommended bids given reports and \( p_i : S \times I \to \mathbb{R} \) is the transfer payment required of ring member \( i \) as a function of the reports made to the ring 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 ring member \( i \) given its report as \( \tilde{p}_i : \mathbb{R} \to \mathbb{R} \). A collusive mechanism \( (\mu, p) \) is incentive compatible if \( \forall i \in K, \forall (v_i, v'_i) \in S_i^2, \forall \psi_i : B_i \to B_i, \)

\[
E_{v_{-i}} \left( \int_B \pi_i(v_i, b_i, b_{-i}) d\mu(b_1, ..., b_k \mid v_i, v_{-i}) \right) - \tilde{p}_i(v_i) \geq E_{v_{-i}} \left( \int_B \pi_i(v_i, \psi_i(b_i), b_{-i}) d\mu(b_1, ..., b_k \mid v'_i, v_{-i}) \right) - \tilde{p}_i(v'_i). \tag{1}
\]

Condition (1) captures two types of incentive compatibility constraints. It ensures that ring members report truthfully to the mechanism, and it also ensures that ring 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 ring member in the number of bidders it registers with itself as the underlying identity.) Ring members use the information contained in their recommendation to update their beliefs about
the recommendations made to the other ring members and to determine their optimal registration and bid behavior. In an incentive compatible mechanism it is optimal for ring members to obey the recommendation of the center given their posterior beliefs.

The mechanism is ex-ante budget balanced if \( E_{v_k} \left( \sum_{i \in K} \tilde{p}_i(v_i) \right) = 0 \), and participation in \( \mu \) is strictly individually rational if \( \forall i \in K, E_{v_i}(\int_{B} \pi_i(v_i, b_i, b_{-i}) \mu(b_1, ..., b_k \mid v_i, v_{-i}) - \tilde{p}_i(v_i) \) is greater than ring member \( i \)'s ex-ante expected payoff when all bidders play non-cooperatively. We focus on incentive compatible, ex-ante budget balanced, strictly individually rational mechanisms.

When registration-related information is revealed prior to the bidding process, then the ring’s bid recommendation is a mapping from registration outcomes to bid vectors. This allows the possibility that a ring could revert to non-cooperative bidding at the auction if certain registration outcomes occur. In addition, the information \( I \) included in the transfer payment mapping would include registration-related information.

For ascending-bid auctions, a bidding recommendation must specify behavior for all possible observable histories of play, including revealed registration outcomes and information revealed as part of the bidding process. Rather than introduce the notation required to define formally a collusive mechanism for an ascending-bid auction, we elaborate below where needed.

3 Results

3.1 No restrictions on payments

If we allow payments from all ring members, regardless of whether they win the auction, then a bidding ring can suppress all ring competition 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 ring members, including those instructed not to bid at the auction.\(^{13}\) The mechanism of Marshall and Marx is ex-ante budget balanced, but only requires a payment from the highest-reporting ring member. In that mechanism, the highest-reporting ring member pays the center an amount equal to the expected surplus that a bidder with

\(^{13}\)Graham, Marshall, and Richard (1990) show that a side payment scheme that is commonly employed by practicing rings when its members are heterogeneous allocates each ring member his Shapley value.
value equal to the second-highest report would receive if it were to bid at the auction against the outside bidders. The expected value of this payment is distributed among all the ring members so that the mechanism satisfies ex-ante budget balance. The bid recommendations are 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 ring members bid zero. Given this mechanism, it is an equilibrium for all ring members to report their values truthfully and follow the bid recommendations of the center. One can easily show that individual rationality is satisfied strictly.\footnote{This mechanism also satisfies strict interim individual rationality, which applies if ring members make their participation decisions after learning their values.}

These mechanisms 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 ring members, the first-best collusive outcome can be achieved at any second-price or ascending-bid auction, 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 ring might prefer a mechanism that only required a payment from the highest-valuing ring when that ring member wins the object at the auction. This is particularly relevant for procurement auctions because a winning ring member may be able to fund transfer payments from auction proceeds or use subcontracting arrangements with other ring members in lieu of cash transfers.\footnote{Subcontracting arrangements were used to transfer payments between ring members in U.S. v. Metropolitan Enterprises, Inc. (728 F.2d 444, 1984), and U.S. v. Inryco, Inc. (642 F.2d 290, 1981).} The ring may also prefer payments only from winners is the liquidity required to make the payment will come from the object being sold. In the next section, we consider collusive mechanisms with this restriction.

### 3.2 Payments only from winners

If the auctioneer or auction process reveals the identity of the winner, then a bidding ring can condition transfer payments on that information. The mechanism of Graham and Marshall (1987) allows a bidding ring to suppress all ring competition while only
requiring a payment from a ring member if that ring member wins the auction. In this mechanism, ring members make reports to the center and the center recommends that non-highest-reporting ring members bid below the reserve price at the auction, while highest-reporting ring member bids its report at a second-price auction or up to its report at an ascending-bid auction. If the ring member wins the auction, it pays the center nothing if the auction price is greater than the second-highest report from the ring. If the second-highest ring report exceeds the price paid at the auction then the winning ring bidder pays the center the difference between the second-highest report and the price at the auction. Given this payment rule, a ring member has no incentive to over report because if doing so makes the difference between the ring member’s report being highest and not, then it means that the second-highest report is greater than the ring member’s value, and then the payment rule guarantees that the ring 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 ring member’s report being highest and not, then since the highest-reporting ring member bids truthfully at the auction, the deviating ring member obtains no collusive gain. Ex-ante budget balance is achieved by dividing the ex-ante expectation payments to the center among the ring members as a fixed ex-ante non-contingent payment.

This collusive mechanism fails if the ring cannot condition transfers on the true identity of the winner. This conditioning might not be possible for several reasons. The auction process might not reveal any information about the identity of the winner other than notifying the winner that it won and losers that they did not win. Or, the auction process might reveal information such as the bidder number assigned or the name supplied at registration, but this information might be insufficient for the ring to know the true identity of the winner. Or, multiple registrations by ring members might allow them to create bidders that cannot be linked to them as the underlying identity, although a ring may be able to combat this possibility if it can observe the presence of multiple registrations by using a mechanism that reverts to non-cooperative play in that case. Or ring members might not be able to observe subcontracting or other arrangements between bidders that could link the winning

\footnote{In a later section of the paper, Graham and Marshall describe optimal “disguised” bids by the \(k - 1\) lowest-valuing ring members. These meaningless “competitive” bids are submitted by the ring so that the auctioneer cannot infer whether bids are coming from a ring or non-ring bidder.}
bidder to a ring bidder and the underlying identity.

**Proposition 2** When a cartel can only collect payments from a ring member that wins the auction, the first-best collusive outcome can be achieved at any second-price or ascending-bid auction if the auction process reveals the underlying identity of the winner.

*Proof.* The proof follows from our assumption that the price paid is revealed and the results of Graham and Marshall (1987). Q.E.D.

Proposition 2 shows that a restriction that the ring only collect a payment from a ring 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 ring members to learn the true identity of the winner, then the result changes.

**Proposition 3** When a cartel can only collect payments from a ring member that wins the auction, the first-best collusive outcome cannot be achieved at a second-price auction if no registration-related information is revealed and the auction process allows ring members to bid through a bidder for which it is the underlying identity, but whose underlying identity is not revealed if it wins.

*Proof.* Consider a first-best collusive mechanism at a second-price auction in which no registration-related information is revealed. In that case, the collusive mechanism’s recommended bids cannot be conditioned on registration-related information, and so to achieve the first-best the collusive mechanism must recommend that the highest-reporting ring member bid its value and that other ring members bid zero. If ring members can bid through another bidder, but the underlying identity of that bidder is not revealed, the highest-valuing ring member can profitably deviate from any ring mechanism that requires a payment if it wins by submitting the collusive mechanism’s recommended bid under a different identity (for which it is the underlying identity). Thus, only collusive mechanisms that require no payments are feasible, and in that case the first-best collusive outcome cannot be achieved because the incentive compatibility constraint for truthful reporting cannot be satisfied—each ring
members would have an incentive to report a value equal to its maximum possible value. Q.E.D.

Proposition 3 shows that rules exist for second-price auctions that prevent a ring from achieving the first-best collusive outcome using a mechanism that only collects payments from a ring member that wins the auction. When ring members can register bidders whose underlying identities cannot be traced to them, ring members prefer to use such a bidder to avoid having to make payment to the center in the event that they win. Thus, first-best collusion cannot be sustained. In particular, if the use of shills is possible, then the mechanism of Graham and Marshall (1987) no longer works because the highest-valuing ring member can disguise its identity and thereby avoid having to make a payment to the ring.

If we restrict attention to collusive mechanisms that only collect payments from a ring member that wins the auction, then in the environment of Proposition 3, correlating devices with no transfers are the only available mechanisms for collusion. We provide results for mechanisms that do not use transfers in Section 3.5.

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

**Corollary 1** At a second-price auction, the revelation of the underlying identity of the winning bidder can be pro-collusive.

Proposition 3 implies that auction processes that facilitate the ability of ring members to bid under second identities can be anti-collusive.

**Corollary 2** At a second-price auction, allowing bidders to disguise the underlying identity of a bidder can be anti-collusive.

Corollary 2 suggests that subcontracting and resale agreements arranged prior to an auction might be anti-collusive if they establish a second identity under which a ring 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 ring members (see Kovacic et al., 2006).

Proposition 3 specifies that no registration-related information be revealed. If registration-related information is revealed and that information allows a cartel to
observe whether one or more ring members have established bidders for which they are the underlying identity, but whose underlying identities are not revealed and will not be revealed by the auction process, then the first-price collusive outcome can be restored. A cartel can use a mechanism that specifies that bidding revert to non-cooperative bidding if such bidders are established, which means a ring member receives no benefit from registering such a bidder. For example, bidders might know that there are $k$ ring members and $n - k$ outside bidders. In this case, the observation of more than $n$ registered bidders could trigger reversion to non-cooperative bidding. Similarly, the observation of a registered bidder whose ownership structure is not common knowledge or information suggesting subcontracting or other contractual relationships between registered bidders could trigger reversion to non-cooperative bidding.

**Corollary 3** At a second-price auction, the revelation of registration-related information can be pro-collusive.

As summarized in Corollary 3, a second-price auction format that releases detailed information about the registered bidders prior to the auction can be pro-collusive because it can allow a ring to police attempts by ring 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 ring member.

In contrast to the above results for second-price auctions, at an ascending-bid auction the presence of bidders whose underlying identities cannot be observed need not eliminate the possibility of first-best collusion. In some environments, we can modify the mechanism of Graham and Marshall (1987) so that ring members cannot profitably register other bidders to disguise their identity.

In the case of a JEA with identities, the highest-valuing ring member can be instructed to register in a way that it is identifiable to the other ring members, and non-highest-valuing ring members can be instructed to stay active up to their values or until the last bidder that is not identifiable as the highest-valuing ring member exits, whichever comes first. Then if the highest-valuing ring member attempts win the object using a different identity to avoid making a payment to the ring, the other ring members remain active up to their values and there is no collusive gain.

In the case of an SEA with identities, the non-highest-valuing ring members can be instructed to bid if the price is less than their values and the auctioneer says
“going, going” and the current high bidder is not identifiable as the highest-valuing ring member. The highest-valuing ring member can be instructed that it must bid before the second “going” whenever it is not the current high bidder and the price is less than its value. Again, if the highest-valuing ring member attempts to win through a disguised identity to avoid making payments to the ring, the collusive gain is lost because the other ring members bid up to their values.

As this argument shows, in both a JEA and SEA with identities, auction rules may permit ring strategies that prevent disguised identities from being used by ring members to cheat on the cartel. In such environments, these ascending-bid auctions are more susceptible to collusion than a second-price auction.

**Proposition 4** When a cartel can only collect payments from a ring member that wins the auction, the first-best collusive outcome can be achieved at a JEA with identities or an SEA with identities, even if no registration-related information is revealed and the auction process allows ring members to bid through a bidder for which it is the underlying identity, but whose underlying identity is not revealed if it wins.

As shown in Proposition 4, the ring’s ability to eliminate ring members’ use of disguised identities as a profitable strategy at ascending-bid auctions does not depend on whether reentry is possible. Cartel strategies exist for both the JEA with identities and the SEA with identities.

**Corollary 4** In some environments, ascending-bid auctions with and without reentry are equally susceptible to collusion, and more susceptible to collusion than second-price auctions.

In contrast, at a JEA without identities or an SEA without identities, ring members cannot modify their bidding in a way that eliminates the benefit to the highest-valuing ring member of bidding through a disguised identity. To see this, note that if the highest-valuing ring member bids exactly as it would have in the absence of shills, but bids through the disguised identity, the auction is observationally equivalent from the perspective of the other ring members (and the outside bidders). So no differential action is possible on the part of the other ring members, and a ring member can avoid having to make any payments to the ring.

**Proposition 5** When a cartel can only collect payments from a ring member that wins the auction, the first-best collusive outcome cannot be achieved at a JEA without
identities or at an SEA without identities if no registration-related information is revealed and the auction process allows ring members to bid through a bidder for which it is the underlying identity, but whose underlying identity is not revealed.

3.3 Implications for bid data

In the modified Graham and Marshall (1987) mechanism, one would expect to observe ring 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 was recently submitted to the U.S. Federal Communications Commission (FCC) by Gregory Rose (2007b, Table 11) in which he alleges that there was a mass simultaneous exit of incumbent broadband providers at the point when Wireless DBS LLC exited. Wireless DBS was a joint venture of the two bid satellite TV companies, and was considered the main potential new competitor to the existing broadband providers, particularly those with a national footprint.

3.4 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. 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, not the ability to reenter or not, which differentiates the JEA and SEA.

Suppose a cartel is restricted to only collect payments from a ring member that wins the object. If no registration-related information is revealed and the identity of the active bidders at a JEA or current high bidder at an SEA are not revealed, then at either an ascending-bid or second-price auction, the cartel can do no better than a random assignment mechanism with no transfers and certainly cannot achieve the first-best collusive outcome. 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 so that registration information reveals disguised identities, then the first-best collusive outcome is possi-
ble at the second-price auction but not at the ascending-bid auction. This highlights how the details of the auction rules together with the auction format 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 ring can control the bids of its members, such as preventing all but one of the ring members from bidding at the auction (see McAfee and McMillan, 1992), and if underlying identities are revealed, 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 where underlying identities are not revealed.

So, statements regarding the relative susceptibility of auction schemes to collusion requires that we specify auction rules, environments, and the mechanism used by the ring.

### 3.5 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 underlying identity 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 underlying identity of the winner, 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 payments cannot be required from ring members, the first-best collusive outcome cannot be achieved.

**Proof.** In order to achieve the first-best collusive outcome, the highest-valuing ring member must bid its value (or some larger amount if the ring is all inclusive) and all other ring members must bid zero. Suppose the existence of an incentive compatible mechanism that recommends that the highest-reporting ring member bid its report (or some larger amount if the ring is all inclusive) and all other ring members bid zero, and suppose no transfers. Given this mechanism, a ring member with value above zero 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, for a non-all-inclusive ring, 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. For an all-inclusive ring, if the deviating ring member’s value is 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.

Propositions 2 and 6 show that when a ring can only require payments from a ring member who wins the auction, if an auction does not reveal the underlying identity of the winner, then the profitability of collusion is reduced, but not necessarily eliminated. In this case, the center can only play the role of a correlating device, and this may or may not 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.

We present an example 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 
\[
\int_0^v v dF(v) = \int_0^v (1 - F(v)) dv,
\]
but expected bidder surplus in the non-cooperative equilibrium (in non-weakly dominated strategies) of the second-price auction is 
\[
\int_0^v F(v)(1 - F(v)) dv,
\]
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 \( \{0, 1, 2, \ldots, 7\} \), then in the non-
cooperative equilibrium expected bidder surplus is 2.6667, expected revenue is 2.6667, and expected total surplus is 5.3333. Under the correlating device that randomly assigns one bidder to bid zero and the other to bid 7, expected bidder surplus is 4, expected revenue is zero, and total surplus is 4. Under an optimal correlating device, expected bidder surplus is 4.3333, expected revenue is 0.6667, and total surplus is 5. So the optimal correlated equilibrium does better than the fully random correlating device in terms of efficiency, and both bidders and the auctioneer capture some of that efficiency gain.

4 Discussion

The results of this paper suggest that both auction design as well as actions of auctioneers can inhibit collusion. Prior to an auction, steps can be taken to facilitate the use of disguised identities by potential ring members. During ascending-bid auctions, information on the identities of the active bidders and 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.

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 the possibility that ring members could disguise their identities.

\footnote{An optimal correlating device is described by $\Pr(b_1, b_2 \mid r_1, r_2)$ defined as follows:}

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However, in this paper, we show that the possibility of disguised bidders may force a ring at a second-price auction to forfeit collusive gains by relying only on a correlating device with no transfers. This shows that there is a difference between ascending-bid and second-price auctions insofar as the susceptibility to collusion.

Although “transparency in bidding” has been touted by the federal government, but certain kinds of transparency can facilitate collusion. Specifically, increased transparency in terms of increased observability of bidder identities, particularly 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, real-time transparency is pro-collusive. Post-auction transparency, where auction results are made public after the conclusion of the auction, should be sufficient to monitor the government.

Additional benefits associated with suppressing information on the identities of active bidders and current high bidders are possible in simultaneous multiple object auctions, such as those run by the FCC. 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.

18See Rose (2007a) and (2007b).
References


