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COLLUSION IN AUCTIONS*

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Abstract

Despite substantial legal evidence of collusion in auctions, there has been very little theoretical or empirical work on this subject by economists. This survey paper discusses mechanisms that are likely to facilitate collusion in auctions, as well as methods of detecting the presence of these schemes. The principal message of this paper is that the presence and the characteristics of collusive mechanisms depend critically on the nature of the object being auctioned, and on the particular auction rules. Accordingly, empirical work should be tailored to specific cases. We highlight these issues in the context of two canonical data sets; namely, procurement contract data in which seller heterogeneities are important, and data on mineral rights auctions, in which uncertainty about the value of the object is considerable.

1. Introduction

There has been very little theoretical or empirical work on collusion in auctions. (The attached reference list is intended to be comprehensive.) However, beginning with Addyston Pipe, there is substantial evidence of collusion in the auctions cited in the legal antitrust literature in the U.S. According to Froeb (1988), 81 percent of the 319 Sherman Act Section 1 criminal cases filed by the U. S. Department of Justice from November 1979 to May 1988 were in auction markets. This survey paper discusses mechanisms that are likely to facilitate collusion, and methods of detecting the presence of collusion, based on our reading of this evidence and the existing economics literature. We will refer to auction design issues, as well as activities of would-be colluders.

The principal message of this paper is that the presence and characteristics of collusive mechanisms depend critically on the nature of the object being auctioned, and on the particular auction rules. Accordingly, empirical work should be tailored to specific cases.

We are interested in whether a potential victim or an antitrust agency can determine whether collusion is occurring and, if so, how to combat it. In Froeb's (1988) sample of Section 1 cases filed in auction markets, the victim was a government agency (federal, state, or local) in 75 percent of the cases. It is not obvious whether collusion in a government sponsored auction is more or less likely to be detected and prosecuted than it is in a private auction market. Cases in which a government is the intended victim may be of more interest to policymakers. Collusion to counteract the market power of a private monopoly seller may not lead to inefficiencies. Only the size of monetary transfers may be at stake in private markets.

The empirical question we attempt to address is one familiar to industrial organization economists; namely, can we distinguish between collusive and Nash, or relatively competitive, equilibrium behavior, given available data? Clearly, the answer to this question depends on the form collusion takes, as well as the nature of any non-cooperative equilibria.

To lend some concreteness to our discussion, we consider two canonical data sets which are similar to those studied in recent empirical work. Not incidentally, such data have motivated much of the existing theoretical work on both cooperative and noncooperative behavior in auctions, as well as the literature on optimal auction design. (See the surveys by Milgrom (1985, 1987) and by McAfee and McMillan (1987).)

In Section 2, we discuss a stylized procurement contract auction in which a potential buyer solicits bids from a number of sellers, who specify the price at which they are willing to provide the specified service. For example, a state government agency may offer a highway construction contract. We argue that seller heterogeneities can be important, insofar as sellers differ in their costs of providing the service. To the extent that the probability distribution of the heterogeneities is qualitatively more important that any uncertainties concerning aspects of the job that affect all sellers' costs symmetrically, such sales are best modelled as independent private value (IPV) auctions. In any event, we will focus our attention on IPV procurement auction data.

We then consider a canonical common value auction data set in Section 3. In this case, a single seller offers a good, or a set of goods, for sale. While agents may have disparate prior beliefs about the value of the object being sold, well-functioning resale markets and durability of the object will ensure a common ex post valuation. For example, in the offshore oil and gas lease auctions run by the U. S. Department of the Interior, there is considerable ex ante uncertainty about the potential value of a lease. The size of the pool is unknown, and there may be uncertainty about the future prices of oil and gas. Nevertheless, these are common or symmetric valuation uncertainties. Furthermore, they swamp any realistic distribution of exploration or extraction cost heterogeneities.

In Section 4, we conclude with a plea for further theoretical and empirical research on these matters. We hope to provide some direction for such research with our ensuing comments. Interested readers are also referred to Froeb (1988), who discusses whether mergers in auction markets are likely to facilitate collusion.

2. Independent Private Value Auctions

This Section is concerned with independent private value (IPV) auctions, in which potential colluders are heterogeneous, and their types independently distributed. Specifically, consider a government procurement auction. For such an auction, or series of auctions, the following data are often available. For each job let, one observes the bid and identity of each firm submitting a bid, and the specifications of each job. In addition, there is often a governmental engineer's ex ante estimate of the cost of the job (i.e., it is formed prior to the solicitation of bids.) In some instances, this estimate will have been announced publicly prior to the auction. (This practice varies across states.) Finally, there is frequently a publicly announced reservation or reserve price for each job, representing the maximum amount the government is willing to pay. However, reserve prices are often kept secret, or a public announcement is supplemented by "phantom" bidding, in which an agent for the buyer acquires the contract. In either event, the government has implicitly rejected all bids, none of them satisfying its unknown (to the sellers) reservation price.

Are these data sufficient to determine whether seller collusion is occurring? First, we have to characterize Nash, or competitive, equilibria in these auctions. If the contract letting is an English auction, with open descending bids, or a second-price sealed bid auction, in which the contract is awarded to the lowest bidder at the second lowest bid, then the Nash equilibrium bidding strategy in IPV auctions is to bid one's true cost. In an English auction, this entails remaining in the bidding until someone else bids below your costs. Recall that this is a procurement auction, in which the low bid wins, assuming quality is being held constant. If, instead, the letting is a first-price sealed bid auction, in which the low bidder is awarded the contract at the price he or she bid, then active sellers will bid their costs plus a strategic markup. This markup will depend on the number of potential bidders, and on the extent to which the firm's cost realization is an outlier. In any of these auction formats, firms will actively participate in the bidding as long as their costs are lower than the announced reservation price, if there is one. (If firms face exposure constraints because of limited credit, then their costs should include any shadow or opportunity costs borne from diverting resources from other projects. Also, their participation decisions may be random.)

A problem with this characterization of Nash equilibria arises if many jobs are being let over time, and firms' costs are correlated across jobs. Two examples come to mind. First, seller heterogeneities may arise because of differing managerial skills, or because sellers own different capital equipment. In either case, seller costs may then reflect both job-specific and relatively permanent idiosyncracies. When private costs are correlated across jobs, then sellers may bid less aggressively. By appearing to be less efficient to their competitors, they may induce less aggressive bidding by competitors in future jobs. Riordan (1985) contains an example of similar "signal-jamming" in an oligopoly context. In a rational expectations equilibrium, no party would be fooled by this behavior, but equilibrium still entails less aggressive bidding. Of course, if heterogeneities arise because of differential experience and learning-by-doing matters, then non-cooperative equilibrium bidding may be more aggressive.

Second, firms' costs may exhibit decreasing returns to scale. An extreme example of this would be binding capacity constraints. Firm cost heterogeneities then arise from backlogs of jobs in process. As Zona (1986) has demonstrated, optimal closed-loop Nash equilibria of repeated auction games with decreasing returns to scale entail an alternating pattern of winners. Auctions tend to be won by firms with little or no backlog. Any inclination to view bid rotation patterns as <u>per se</u> evidence of collusive behavior is therefore unwarranted, absent evidence that diseconomies of scale are unimportant. Job rotation may be the efficient outcome of a competitive bidding process when capacity constraints or decreasing returns matter.

A cartel's problem is to designate a winner for each job, and then to obtain the contract at the highest possible price. If the cartel does not include all active bidders, then it must bid optimally against outsiders. The cartel must also decide how many bids to submit.

The designation of a winner can be accomplished by a pre- or post-auction knockout auction, in which cartel members alone bid for the right to win the job. Transfer payments can then be used to compensate non-winners, or else the cartel can rely on the law of large numbers to even up payoffs in the long run. Clearly, the presence of transfer payments or extensive communication could be taken as clear evidence of collusion. If these are treated as per se violations, as in other oligopoly markets, there are few obvious social costs. Absent such evidence, it may be difficult to detect collusion.

The cartel may rely on the buyer to designate the winner, by submitting many identical bids, below any announced or perceived reserve price. (If the cartel is inclusive, they should bid the reserve price. If not, they should optimize versus the other bidders.) Mund (1960), among many others, has argued that the submission of many identical bids is an unlikely Nash equilibrium, particularly when sellers' costs are heterogeneous. Nevertheless, it is again important to obtain some knowledge about sellers' costs.

Alternatively, the cartel may employ a predetermined bid rotation scheme, such as a "phases of the moon" system, to designate a winner. As described above, bid rotation is consistent with some competitive equilibria. The detection of collusion problem is exacerbated if the winning bid is accompanied by cartel phantom bids, which exceed the winning bid. These bids may be submitted to create the appearance of competition. If the buyer is uncertain about the true cost distribution, phantom bids may be useful to manipulate the buyer's expectation regarding the likely price of future jobs, as suggested by Feinstein et. al. (1985). To the extent that data on government engineers' prior estimates of the costs of various jobs depend on previous bidding patterns, such data should be regarded as potentially biased estimates of true costs. For example, a sequence of high winning bids, together with many phantom bids that exhibit little dispersion, may induce the buyer to anticipate too high costs for future lettings. Future reservation prices would then be higher, and so would future cartel profits.

The above discussion suggests that, given the available data, it would be very difficult to detect the presence of an inclusive cartel that submitted phantom bids. What is required is access to detailed prior information about the distribution of costs, or access to reliable cost data that permitted the computation of realized profits. If the cartel was not inclusive, or active only on a fraction of job offerings, then it may be possible to employ noncartel bids, or bids in competitive auctions, to determine the size of the cartel markup on individual jobs.

For example, in British Columbia, a portion of each year's allowable cut timber is set aside and sold to eligible loggers and sawmillers through a series of public auctions which are either English or first-price, sealed-bid. Paarsch (1989) contrasts participation and bid decisions in these two classes of auctions under the assumption that the underlying distributions of cost heterogeneities are the same, and finds that behavior differs in ways which are inconsistent with non-cooperative models of bidding. One explanation, which has both anecdotal and statistical support, is that some of the bidders who attended the oral auctions colluded.

The incidence of collusion may not be as frequent as the above discussion might lead one to expect. First, any incipient cartel must confront the usual problem of detecting and deterring cheating, and its long run returns may be limited by entry. Second, the seller can alter the auction rules to limit a cartel's effectiveness.

Prospective entry will not inhibit cartel behavior if seller heterogeneities are persistent. For example, in a sample of New York State highway construction auctions, Zona (1986) found evidence of collusion only on larger jobs, which required access to specialized capital equipment. Thus, if some production costs are sunk, competition may be limited in some auctions to larger firms with such investments, and cartel formation may be more profitable. This assumes that there is not a well-functioning rental or used-goods market for the relevant equipment. Otherwise, fewer costs are sunk, and prospective entry will limit cartel returns.

Detection of cheating on a cartel agreement is straightforward, insofar as some cartel member underbids the designated winner. It is less straightforward when many identical bids are to be submitted, if only the identity of the winning bidder is announced, and not his or her bid. Then the cartel must monitor win frequencies over a number of jobs, in order to detect statistically significant deviations from allotted shares.

If auctions are held frequently, the cartel can rely on threats of expulsion from the ring, or collapse of the agreement, to sustain collusion. Then, short-run gains to cheating must be weighed against the discounted loss of further profits, adjusted by the probability of inducing punishing behavior. Robinson (1985) has noted that cheating can be deterred in a one-shot English or second-price sealed bid auction even without any threats of future punishment. In the former case, the designated winner can immediately respond to any unanticipated bid, by remaining in the auction until the price falls to his or her true cost. If the designated winner is the low cost firm in the cartel, it will not pay for any other firm to cheat. Similarly, the optimal strategy for the designated winner in a sealed-bid second price auction is to bid one's true cost. Again, it will not pay for any higher cost firm in the ring to bid less than this amount.

Nevertheless, incentive constraints may arise in repeated auction environments with nontrivial intertemporal payoff linkages. For example, the coordination problem may be more difficult if the idiosyncratic portion of firms' costs are correlated across jobs, as suggested by Riordan's (1985) analysis of two period subgame perfect equilibria. Alternatively, if firms' costs are decreasing functions of previous capital investments, then incentive compatibility constraints may be more stringent, and cartel profits lower. In this case, firms may initially overinvest in cost reducing expenditures, thereby dissipating rents. On the other hand, the analysis of an oligopoly market with learning-by-doing by Mookherjee and Ray (1987) suggests that, when costs are a decreasing function of cumulative production experience, collusion is no more difficult to maintain. The most severe punishments are independent of the slope of the learning curve, and depend only on the limiting value of unit costs. Further, entry is less effective in limiting collusive returns. It remains to be seen whether these results also hold in repeated auction (as opposed to oligopoly) markets with learning-by-doing.

Even if all potential entrants can be accommodated as part of the ring, so that the ring is truly inclusive, then typical cartel large numbers problems may arise. For example, Cramton and Palfrey (1987) show that the problem of reconciling disparate interests, that arise from cost heterogeneities, can become insurmountable when there are too many cartel members. In addition, Comanor and Schankerman (1976) note that bid rotation schemes are increasingly difficult to design as numbers grow, because of the problems of gathering and disseminating relevant information, and of coordinating allotment procedures.

We now turn to a discussion of options available to the buyer to combat suspected collusion. There are several methods a buyer can employ. Clearly, restricting information flows within the cartel may hinder its ability to detect cheating. For example, the buyer could announce only the identity of the winning bidder, and not its bid (or the losing bids.) This may disrupt schemes that entail the submission of several identical bids. Alternatively, the buyer could refuse to choose randomly from a set of identical bids. The bids could be ranked in alphabetical order, say. The cartel would then have to design a more sophisticated allocation scheme.

Similarly, the buyer could adopt a secret selection rule, occasionally choosing the second lowest bidder, for example. If actual bids are not announced, it would be very difficult for a cartel to detect when cheating has occurred. The oligopoly literature suggests that increasing this sort of uncertainty can be fatal to a collusive agreement. Unfortunately, such mechanisms are corruptible. There would be an incentive for a seller, or a set of sellers, to bribe the buying agent. (This assumes that the buying agent does not capture all the rents on the buyer's side.) Since any such rule would necessarily entail choosing a winner in an unpredictable manner, it would be difficult to detect corruption by the buying agent from data on bids and winners alone.

If the buyer suspects that a ring is operating, the reservation price could be decreased, either secretly or publicly, to decrease the expected purchase price. McAfee and McMillan (1987) demonstrate that, if the reserve price is chosen optimally, members of a ring can be worse off than if they had behaved noncooperatively, with a corresponding higher optimal reserve price. Of course, it is then in a ring's interest to disguise its operation, via phantom bidding and secret knockout meetings.

First-price sealed bid auctions or oral auctions with a pre-specified time limit may be less susceptible to collusion. In the former case, the cartel cannot react instantaneously to cheating, but must instead rely on expulsion threats or other future retaliatory measures. In the latter case, it is impossible to react to a defector's bid if the bid occurs just before the auction shuts down. Again, threats of future punishment must be relied on.

If the buyer is letting many contracts, a simultaneous auction may be preferable to a sequential series of auctions. Retaliation would be delayed, and therefore less effective as a disciplinary device, in the former case.

Similarly, the gains to cheating would be larger, as a ring member could defect in many auctions at once. However, sellers may bid less aggressively in a simultaneous auction if they face capacity or other sorts of exposure constraints.

Our earlier discussion of Nash equilibrium and collusion indicates that the nature of competitive and collusive behavior is likely to depend upon the specific properties of the auction mechanism. This suggests a buyer strategy in which alternative auction mechanisms are used to purchase jobs. Since the distribution of the unobservable cost heterogeneities is usually independent of the auction mechanism, the buyer can use bid and participation data from different auctions to check for behavioral differences which are inconsistent with non-cooperative behavior, and which may indicate the presence of collusion.

In summary, there is a clear need for further study of repeated IPV auctions. Of special interest are those in which a seller's private values are not independent across auctions. Robinson (1985), Graham and Marshall (1987), and McAfee and McMillan (1987), among others, have initiated the study of collusion in one-shot IPV auctions, and further work on repeated auctions would be welcome.

3. Common Value Auctions

Consider an auction for the exploration and extraction rights of a set of federal offshore oil and gas leases. As we pointed out in our introduction, this can safely be modelled as a common value auction. For these leases, a wealth of data is typically available. (Similar data are available for state oil and gas lease auctions.) As in the IPV case, one can observe the set of actual bidders and their bids, any announced minimum reserve price and royalty rate, and the government's estimate of the value of the tract. This last variable should be viewed with some suspicion, for it may be a function of the submitted bids.

What distinguishes common value auction data from IPV data is that it may be possible to estimate the realized lease value, and so ex post profit figures can be constructed. In the oil and gas lease example, annual drilling and production histories, together with price sequences and some discount rate, can be used to determine bidders' net profits. See Hendricks, Porter and Boudreau (1987) for an example of these calculations. Unfortunately, it is much more difficult to determine what the bidders expected the lease to be worth. Thus, high profits could be a signal of either collusive behavior, or of unexpectedly large deposits, high prices or low costs. Of course, one might be suspicious of persistently high profits over a long period of time.

Nash equilibria of these auctions depend critically on the nature of information available to potential bidders prior to the sale. If two or more bidders know the value of the lease, then competition will result in zero profits. Relatively uninformed bidders will not participate, and knowledgeable firms will bid away any profits, regardless of the mechanism, when the value exceeds the reserve price. Positive profits, after netting out all appropriate costs, are then compelling evidence of collusive bidding.

More typically, however, bidders are very uncertain about the value of the object. In the offshore oil and gas lease auctions in the Gulf of Mexico from 1954 to 1969, only about half of the tracts explored were productive (i.e., some oil or gas was extracted), and a third of the leases were never explored. After 1973, there was considerable uncertainty concerning future price paths. Finally, exploration and extraction costs were uncertain for leases off the North Slope of Alaska, for example. Furthermore, while bidders have access to essentially the same seismic data prior to a sale, their assessments of that data can differ considerably. Accordingly, these bidders have been modelled as imperfectly informed, with differing signals about the value of the lease.

If a bidder thinks that winning the lease may be profitable, he or she will bid some fraction of the estimated value. This fraction will depend on the number of potential bidders, as opposed to the actual number, as well as on the accuracy of the bidder's prior information. Here, accuracy relative to other bidders is strategically important, as is absolute accuracy if bidders are risk averse. Competitive bidding will then result in a number of bids, and this number will vary according to prior expectations about tract value. Not all active bidders will necessarily participate in all tract sales, because reserve prices are positive, and because not all tracts have positive expected profits. (In the Gulf of Mexico, more than two-thirds of all tracts sold had negative ex post net profits.) Also, exposure constraints may be binding. Therefore, absence of bids by active firms cannot be taken as prima facie evidence of collusion. Further, in many auctions, it is difficult to identify the set of active firms, as opposed to the set that actually submits a bid.

A cartel or bidding ring must also decide whether to bid on a given tract and, if so, how much. As in the IPV auction, there are many possible collusive mechanisms. Two which may be open to detection are bid rotation and bid shading. For any bid rotation scheme involving a subset of the active firms, the ring would assign some firm to bid on each of the tracts they were interested in. Their participation probabilities would therefore be complementary. Since only imperfect proxies for ex ante beliefs are likely to be available, the alternative hypothesis of competitive bidding implies that, on average, unexplained residuals in participation equations should be positively correlated across firms. Evidence of negative correlation within a subset of firms could therefore be taken as indicative that a bid rotation scheme was present. Unfortunately, this sort of test would not be useful if bid rotation entailed firms submitting lower phantom bids when they were not designated to submit the highest bid among the ring.

Under a bid shading scheme, participating firms would systematically decrease their bids as a fraction of their estimate of value, relative to the competitive bidding strategy. The technique described in Section IV of Hendricks et. al. (1987) is designed to detect this sort of scheme. This technique consists of looking at the set of tracts a given firm bids on, taking as given ex post gross profits and other firms' bids on those tracts, and varying bids by that firm alone proportionately. For example, by doubling that firm's bids, it would have acquired more tracts, and earned additional profits, but it would have paid more. One can then identify what bid factor (i.e., what multiple of actual bids) would have maximized that firm's net ex post profits. If firms behaved according to risk neutral Nash equilibrium behavior, and had unbiased ex ante expectations, then their actual bidding strategy should have been nearly optimal. If, however, there was a bid shading scheme among some subset of the firms, then, within that subset, any of those firms could have increased their individual (as opposed to the group's) profits by increasing its bids systematically. Similarly, in a quantity-setting oligopoly game, any firm in a collusive scheme can earn more profits by increasing its own output. Unlike the oligopoly case, for auctions it is not necessary to estimate demand and cost functions to conduct this experiment. Unfortunately, it is necessary to assume risk neutrality and to be satisfied that expectations are unbiased. What looks like collusive underbidding may be accounted for by risk aversion or by unduly pessimistic expectations. Once again, several types of evidence are required to prove that collusion is present.

In drainage oil and gas lease auctions, in which firms owning adjacent tracts have access to better information than do other firms, we were able to identify the better informed firms. (See Hendricks and Porter (1988).) We were able to assert that bid coordination may have occurred among this set of firms because, first, the highest bid of these firms appeared to be independent of their number and, second, the highest bid of the relatively uninformed firms was only weakly decreasing in this number. Competition would imply that the former maximal bid should have been an increasing function of this number, and the latter maximal bid a decreasing function. In the latter case, more informed firms exacerbates winner's curse considerations, as one should be increasingly cautious as the number of competitors who know more than you do increases. It is worth noting that bid coordination was legal in these auctions. Nevertheless, our techniques may be applicable to other common value auctions with asymmetric information. Our paper contains further documentation of these claims.

If there is a costly information acquisition process prior to a common value auction, collusion may be more difficult than in IPV auctions. First, it may be impossible to induce participants to divulge their private information in pre-auction meetings. In that case, some of the benefits (to the participants) of colluding will be foregone. In a common value auction, there can be considerable gain from information exchange, particularly if the ring then has more accurate information than do other bidders. Graham and Marshall (1987) and Robinson (1988) have discussed methods of overcoming this problem in IPV auctions with presale knockout auctions, but these methods do not translate straightforwardly into the common value setting.

Second, there may be a problem of free-riding on the information gathering activities of other ring members. Information shared within a coalition is inherently a public good, so free-riding could be an acute problem. Any ring would presumably be better off pooling its pre-sale exploration activities. Of course, any such pooling would be easier to detect than bid coordination.

In the federal offshore oil and gas lease sales, joint ventures or bidding consortia are legal. After 1975, joint ventures involving two or more of the eight largest oil companies (as determined by world hydrocarbon production) were prohibited, because of concerns about limited competition. In a joint venture, two or more firms agree to submit joint bids on a set of tracts, and how to share the profits on the tracts that they win. These shares may be tract-specific. Joint ventures often form just prior to sale, after firms have already acquired seismic information about tracts. These ventures tend to form for bidding in specific areas and sales. However, there are a number of cases in which firms formed a joint venture prior to investing in seismic surveys, and shared the costs of gathering these data. These joint ventures were usually active on a large number of tracts, and in more than one sale. As suggested by our previous discussion, these latter ventures were more stable.

Bidding consortia may serve purposes that enhance efficiency. They may provide a mechanism for entrants to pair with firms with prior experience in offshore exploration, and so to reduce expected drilling costs or risk. They may also facilitate entry into the industry by allowing small firms to overcome capital constraints. Joint ventures between small and large firms may essentially be agreements in which the small firm trades information or expertise for capital. Consequently, per se illegality of joint bidding may be unwarranted.

In some instances, the causes of formation of a joint venture have testable implications for bidding behavior of the consortium and its competitors, and their relative returns. For example, if joint ventures form to pool information and their formation is observable, solo bidders are likely to be less precisely informed and, as a result, should bid less aggressively. The profits of the joint venture in this case will include an information premium which is not earned by a solo bidder. A purely collusive joint venture, however, should serve to increase the relative returns of solo bidders. As is often the case, it is then better for a firm if other participants collude, and to free ride on their jointly profitable activity.

In general, consortia of bidders may form for many reasons, not all of which lead to reductions in sellers' expected revenues or in welfare. While it may not be easy to discriminate between collusive motives and those of risk avoidance, capital pooling or information sharing, careful analysis of data can lead to the rejection of some of the competing hypotheses.

As an extreme example of socially beneficial bidding consortium formation, suppose information exchange results in exact knowledge of the value of an oil lease. Then consortia will bid only on tracts of positive value, and after the auction will not engage in nonproductive drilling programs. If these consortia are not inclusive, then the seller will benefit as well, as competition will drive bids up to true lease values. Even with risk neutral firms, without consortium formation, bids would have been shaded down to account for the possibility that the tract was dry and net profits therefore negative.

Most of the methods, discussed in the previous section, that a buyer could employ to combat bidding rings in IPV auctions are also pertinent for sellers in common value auctions. Again, the seller should be careful not to hinder bidder coalitions arising for noncollusive reasons, in the event that the seller may also benefit from such consortium formation. See Froeb and McAfee (1988) for a discussion of how the government could deter bid rigging in timber rights auctions.

Further work on coalition formation in common value auctions would be welcome. Also of interest are situations in which costly information gathering precedes the auction. Unfortunately, common value models can be very cumbersome to work with. See Matthews (1984) for an example of pre-sale information acquisition in a noncooperative auction game.

4. Conclusion

We apologize for the conjectural nature of this paper. To some extent, this is a result of the paucity of auction models with collusion. As Froeb (1988) documents, collusion in auctions is a widespread phenomenon, however, and may result in substantial additional expenditures (in procurement auctions) or revenue losses (in mineral or timber leases), at all levels of government. Procurement auctions that allocate orders to inefficient sellers, or lease auctions that distort exploratory incentives, can also result in nontrivial welfare losses. Therefore, further theoretical and empirical study of collusion in auctions seems to be warranted.

While there has been little prior theoretical or empirical work on collusion in auctions, there is a large theoretical literature on noncooperative behavior in auctions. See, for example, the list of references in McAfee and McMillan (1987). Furthermore, detailed data sets, similar to the "canonical" data sets discussed above, are publicly available. The lack of attention paid to the issues we raise is therefore somewhat surprising.

Finally, we repeat our claim that the presence and the characteristics of collusive mechanisms depend critically on the nature of the object being auctioned, and on the particular auction rules. Accordingly, theoretical and empirical work should be tailored to specific cases.

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