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Working Paper

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CSIO Working Paper, No. 0051

Provided in Cooperation with:

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Suggested Citation: Porter, Robert H. (2004) : Detecting collusion, CSIO Working Paper, No. 0051, Northwestern University, Center for the Study of Industrial Organization (CSIO), Evanston, IL

This Version is available at:

<http://hdl.handle.net/10419/38646>

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THE CENTER FOR THE STUDY
OF INDUSTRIAL ORGANIZATION
AT NORTHWESTERN UNIVERSITY

Working Paper #0051

Detecting Collusion

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Abstract

Detection and deterrence of collusion are longstanding antitrust problems, made difficult because collusive arrangements are usually surreptitious. In this paper, I discuss factors that facilitate or inhibit collusive schemes, as well as circumstances where detection is possible. I describe how industrial organization economists diagnose collusion (both explicit and tacit) among firms.

This year marks the 40th anniversary of the publication of George Stigler's "A Theory of Oligopoly" (Stigler, 1964). My purpose is to describe how to determine when there is a collusive agreement among firms. Stigler's paper has been an inspiration and building block for the ensuing literature on cartels and collusion. There is a sense in which much of the material I cover here is derivative of ideas first advanced by Stigler. I am happy to acknowledge this debt, in the city where Stigler spent most of his career.

In any market, firms have an incentive to coordinate their decisions and increase their collective profits by restricting output and raising market prices. A cartel might also limit new product introductions or quality improvements, although there is less of a consensus on the effects of market power on these aspects of competition. Detection and deterrence of collusion are a longstanding antitrust problem. Collusion includes circumstances where some firms act in unison to raise the prices that they charge their customers, or to lower the price that they pay to acquire goods or services, or to otherwise inhibit competition. These actions are usually surreptitious, either because they are illegal under antitrust laws or because they are intended to be kept secret from the victims.

In this paper I discuss factors that facilitate or inhibit collusive schemes, as well as circumstances where detection is possible. I will describe how industrial organization economists diagnose collusion among firms. Collusion in this instance may refer to either explicit or tacit cooperation. Under explicit collusion, firms communicate directly, whereas under tacit collusion communication is indirect, as firms infer rivals' intentions from their actions or from market outcomes.

In many social settings, cooperation is beneficial, and should be encouraged. I take the perspective of industrial organization economists, or that of antitrust policy, that collusion among firms, if successful, benefits the participants at the expense of their customers or suppliers. From a social perspective, the losses usually outweigh the benefits. For example, if a cartel limits the amount sold relative to competitive levels to drive up the market price, there will be a welfare loss. (See, for example, Tirole (1988).) More generally, there is a welfare loss associated with foregone trading opportunities.

An issue, then, is to determine when collusion is occurring. Collusive schemes are often illegal, and a problem faced by antitrust authorities (such as the U.S. Department of Justice or Federal Trade Commission) is to detect their presence. The methods described below might be employed to provide evidence in an antitrust proceeding, or they could be used during a preliminary investigation. Under the 1993 amendments to the U.S. Corporate Leniency Program (also known as the Corporate Amnesty Program), the first to confess participation in a price fixing conspiracy receives lenient treatment in subsequent criminal proceedings, offset to some degree by the confessor's degree of participation in the conspiracy. In the case of Sotheby's and Christie's conspiracy to raise fees to sellers at their auction houses, Christie's came forward first, and it was Alfred Taubman of Sotheby's who spent time in jail. Sotheby's paid a criminal fine, and Christie's did not. If empirical evidence suggests that a conspiracy may have been active, the parties involved might be alerted of these suspicions, thereby inducing a "race to the courthouse." Note, however, that the Amnesty Program does not grant immunity from civil suits brought by the victims. In the Sotheby's and Christie's case, the firms paid equal civil penalties. (See, for example, Ashenfelter and Graddy (2004).)

Alternatively, antitrust authorities may pursue policies that inhibit successful collusion, by altering characteristics of the economic environment. For example, they may pursue an activist merger policy.

Moreover, in some instances the victims of the conspiracy can take actions to counteract the market power of the cartel, either collectively or when individual victims have market power. The presence of a bidding ring might lead to a re-design of auction rules, say.

It is useful to adopt the perspective of the participants in a collusive scheme. Most cartels encounter operational problems. It is the manner in which a conspiracy deals with these problems that often facilitates the detection of the scheme. In some instances, one can do more than just look for direct evidence of the exertion of market power, such as high and persistent profits that cannot be accounted for by cost or product quality advantages.

I will focus on five potential cartel problems, and provide examples of conspiracies that revealed their presence in the process of addressing the problems. I offer no general detective prescription, apart from the idea that the individual circumstances of the industry in question often suggest what a fruitful line of inquiry might be. Case studies are inevitable.

Problem One: Detection by Antitrust Authorities or the Victims

A time-honored method of detecting collusion is finking by a dissident cartel member or an ex-employee, or the complaints of customers. Such evidence has obvious attractions, but one should be suspicious of complaints by a rival firm not party to the conspiracy. Rivals typically gain from higher prices, and they suffer from more intense competition. Thus, an agreement that harms rivals, such as an R&D joint venture that lowers costs of the firms participating in the venture, may be

beneficial to society. In an auction market, rival bidders could also suffer if a bidding ring pools information about common value components, but in that instance ring formation is not necessarily socially detrimental.

A bidding ring wants to avoid detection by the antitrust authorities if their discussions are illegal, and by a seller who can alter the selling mechanism in response. For example, a seller could raise the minimum bid in an auction, or keep bids secret to make it harder for the ring to maintain discipline. If the ring is not all-inclusive, it may also want to keep its presence unknown to other potential bidders. Bids are typically strategic complements, so that rivals who are certain to participate will bid less aggressively in response to a ring, but other potential bidders may be more likely to submit a bid. An analogous argument applies in a differentiated product market with price setting firms, where new product introductions by rivals can dissipate cartel profits. In an oligopoly market with Cournot competition, quantities are strategic substitutes, and a cartel would prefer to keep its intentions secret even from existing rivals, to minimize the extent to which they free ride on the output reductions of the cartel members.

Antitrust laws that prohibit side payments or direct communication between conspirators increase the chances of there being a dissident. I return to this point below. The Amnesty Program mentioned above increases the incentives of a dissident to report to the authorities. A problem with side payments or direct communication is that they may provide direct evidence in court. Archer Daniels Midland executives served time in prison for their participation in the lysine cartel, despite an unreliable dissident witness (Mark Witacre), because their meetings with co-conspirators had been recorded.

Absent the direct evidence of a dissident, a conspiracy may be difficult to detect. For example, conspirators may act to create the appearance of competition in order to avoid detection. In procurement auctions, bidding rings may submit phony, or complementary, bids, which are designed merely to be higher than the serious bid submitted by the ring. That is, only the lowest bid from the ring is serious. But phony bids, unlike serious bids, may not be related to the likely profits of the bidder in the event that it wins. Porter and Zona (1993) describe a bidding ring involving highway-paving jobs on Long Island in New York. A subset of the firms participated in pre-auction meetings in order to assign low bidding privileges for specific procurement contracts. The conspirators often submitted complementary bids above the low bid. We did not have access to useful contract-specific information, so we focus on the rank order of submitted bids. We show that the order of the bids submitted by non-conspirators was related to observable cost factors such as capacity and a measure of capacity utilization, the backlog of contracts recently won. The lowest conspirator bid was most likely to be submitted by the firm with the lowest cost. In contrast, the order of the higher bids submitted by ring members was not correlated with the same cost measures. Note that a sophisticated cartel could pass this test, for example by inflating all submitted bids above costs by the same percentage.

In addition to creating the appearance of competition, complementary bids may also be intended to manipulate the expectations of the buyer. Feinstein, Block, and Nold (1985) note that many agencies estimate the cost of projects on the basis of past bidding on similar projects. Multiple phony bids close to a relatively high bid may lead an unawares buyer to believe that costs are higher than they are. Feinstein et al. analyze data from North Carolina highway construction auctions, and suggest that contractors were indeed manipulating the information received by the buying agency.

Problem Two: Secret Price Cutting (Unilateral Defection)

There is no honor among thieves. If there is a conspiracy to raise prices above competitive levels, then there is a temptation to cheat on the agreement, if defection is unlikely to be detected by rivals and subsequently punished. That is, unilateral deviation from non-Nash equilibrium actions is profitable, at least in the short run. The problem is that the parties to an illegal conspiracy cannot rely on the courts to enforce their agreement, and so any agreement must be self-enforcing.

In a repeated game, even if there are no direct payoff linkages between periods, more collusive outcomes are possible. By conditioning their behavior on the past actions of other firms (or their inferences about these actions), a cartel can induce more cooperative outcomes. Relatively aggressive behavior is dissuaded by the threat of “punishments” in the future. As long as firms value future payoff streams highly, and the threatened punishment is rapid, sure, and severe, these schemes will induce collusive behavior. Defections must be detected with high enough probability, after not too long a period, and the optimal response must be harsh, within the limits of the punishment itself being self-enforcing.

Collusion will be abetted by any practice, such as information gathering and dissemination by a trade association, which speeds the detection of, and hence response to, defections from an agreement. One role of trade associations is to make pricing and sales figures publicly available as quickly as possible. This facilitates the rapid detection of price chiseling. An instructive case study is described by Albaek, Mollgaard, and Overgaard (1997). The Danish Competition Council in 1993 adopted a policy that was intended to make markets more transparent. In some industries, prices were set in private negotiations, and there was a concern that some buyers may not have been aware

that they were paying high prices. The Council probably thought that publicizing transaction prices would foster more informed buyer search and therefore induce more competitive pricing. Albaek et al. examine what happened in the Danish concrete market. The government collected and reported transaction prices for some types of concrete, but not all. Albaek et al. document that prices in the former category increased by 15 to 20% after the government began reporting prices, but prices in the latter category rose only 1 to 2%. They argue that the difference in price changes cannot be attributed to other factors. The government policy appears to have resulted in more collusive outcomes.

Price matching clauses also permit the monitoring of rival prices, as potential customers will report any better offers that they have received. Customers are not disinterested participants, of course, and they have an incentive to claim that rival price quotes are low, but the price matching policy can apply only to written offers.

Detection is also easier if the price structure is relatively simple. Some have argued that this is a motive behind the adoption of base-point pricing schemes, under which prices quoted to buyers include transportation costs from a given point of origin (the base-point), no matter where the product is actually shipped from. Similarly, Genesove and Mullin (2001) describe how the Sugar Institute acted to standardize the pricing of sugar in the early 1900s.

If rival cheating can be detected, then the cheater can be singled out for punishment. A legal cartel could require that a defector sacrifice a bond with, or pay a fine to, a trade association. Alternatively, price wars in the defector's territories can be an effective punishment. For example, trash haulers in Los Angeles were accused of "agreeing not to steal each other's customers, and punishing competitors who would not go along by offering their customers below-cost rates." (*New*

York Times, March 14, 1989.) Such threats are often sufficient to inhibit cheating, and so there may not be any need to resort to the threatened punishment.

The corn syrup conspirators, Archer Daniels Midland et al., employed a transfer scheme where firms with market shares above their allotment compensated their co-conspirators for foregone market share at the agreed-upon market price. If market shares are measured correctly, such a scheme eliminates the incentives to steal market share.

Robinson (1985) points out that a bidding ring has an easier time colluding in second price sealed bid (SPSB) or English auctions. In an SPSB auction, the highest bidder wins, but pays the bid of the second highest bidder, or the minimum bid if nobody else submits a bid. If the designated ring bidder has the highest valuation, and if that bidder bids his true valuation, the other members cannot gain from deviating. Note that bidding one's valuation is a dominant strategy in a SPSB auction when there are no common value elements to payoffs, and hence the designated bidder's optimal strategy does not depend on the competition he faces. The success of the ring then depends on how many potential bidders refrain from bidding, thereby lowering the expected price paid by the designated bidder in cases when it wins. Similarly, in an English (ascending) auction, the serious bidder only needs to outbid other submitted bids. There is then a short run cartel problem only if the serious bidder does not have the highest valuation among the ring members.

Baldwin, Marshall, and Richard (1997) propose an econometric method to detect collusion among a subset of bidders in English auctions. The method applies straightforwardly to SPSB auctions. If bidders have private values, and bidding is competitive, then the winning bid is the second order statistic of the distribution of values, as the highest valuation bidder just outbids the second highest valuation bidder. If a subset of bidders collude, then the winning bid is affected only

if the two highest valuation bidders are ring members. If not, the winning bid remains the second order statistic of the value distribution. If so, then the winning bid falls to the highest valuation among bidders not party to the conspiracy. It will be the third order statistic if this value is the third highest among all bidders. Thus, the winning bid under collusion is a mixture of the second and lower order statistics. As should be apparent, functional form assumptions about the distribution of valuations play an important role in distinguishing between competition and collusion. In the above discussion, there is also an implicit assumption that the cartel is efficient, in the sense that the designated bidder of the cartel is the member with the highest valuation.

In contrast, collusion is more difficult in first price sealed bid (FPSB) auctions where the serious bidder may bid below the valuation of other ring members. The other members could then win the auction at a profitable price, and there are the usual problems associated with deterring unilateral defection. Marhsall and Marx (2004) show that complementary bids may then play a role, if the threat of future punishment is insufficient to prevent defection. The designated ring bidder should bid higher than optimal against non-ring competition, to remove the incentive for other ring members to defect and submit a higher bid. A complementary ring bid should then be submitted just below the high ring bid, to dissuade the designated bidder from bidding less. Thus complementary bids may do more than create the appearance of competition.

Like SPSB auctions, in some multi-unit auction designs, the punishment recourse is within the auction itself. In a multiple-unit simultaneous ascending bid format, such as the mechanism employed by the U.S. Federal Communications Commission (FCC) to sell spectrum for PCS (personal communications services), punishments can be wide-ranging. Defections in the bidding for one object can induce responses elsewhere. Gertner (1995) shows how the simultaneous ascending

structure can facilitate tacit collusion. (See also Milgrom (2000).) An equilibrium of the bidding game involves a partition of the licenses among firms, with each firm submitting a low bid on its set of licenses. The equilibrium is sustained by the threat of running bids up to competitive levels should any firm defect and bid on licenses outside their allotted set. The FCC design permitted new bidding on any license as long as the auction was running, and therefore retaliation in the territory of the deviating bidder was feasible, subject to eligibility restrictions on bids.

In a multi-unit uniform price auction, price is determined by a market clearing condition, where available supply equals demand. The market price is often determined by the lowest winning bid, or sometimes by the highest losing bid. The uniform price mechanism was employed in the United Kingdom and Wales electricity auction market in its early years. (See Wolfram (1998, 1999) for an account. The market has since switched to a discriminatory format.) Bidders can make it costly for rivals to steal market share by bidding low prices for inframarginal supplies and a high price for marginal units. Such a strategy is sometimes referred to as “hockey stick” bidding. A generating unit is inframarginal if it is likely to be called on to supply power, but unlikely to be decisive in determining the market clearing price. If all bidders follow this strategy, and inframarginal generating units account for a large share of industry supply, the market clearing price will be high, but the gains to defection will be low. In this instance, a discriminatory auction, in which each supplying unit is paid the amount of its bid, might induce more competitive bidding.

A more basic problem arises if firms cannot distinguish between cheating and adverse demand conditions. For example, if firms do not observe rivals’ transaction prices, as opposed to list prices, and only know their own sales, then low sales may occur because a firm has been undercut, or because times are bad (as noted by Stigler (1964)). Then a cartel may have to respond to

unexpectedly poor sales by resorting to a widespread price war. If demand is variable enough, there will be occasional breakdowns of collusion, even if no one actually cheats. Price wars in response to unexpectedly poor sales are necessary to keep the incentives to cooperate intact (Green and Porter, 1984).

The Joint Executive Committee was a railroad cartel in the 1880s that transported grain and other provisions from Chicago to the eastern seaboard of the U.S. The trade association allocated market shares to its members, and kept records of shipments and prices charged by the various railroads. However, prices were negotiated individually with clients, and market shares were relatively volatile, so that secret price cutting was difficult to detect. The cartel witnessed about ten price wars in the period 1880-1886, averaging about ten weeks in length. The econometric work of Porter (1983) and Ellison (1994) indicates that the price wars were consistent with shifts in the industry supply curve, and cannot be attributed to observable cost or demand shocks. Instead, they appear to be a reaction to unusually volatile market shares, as predicted by the theory.

Problem Three: Entry

If firms succeed in raising prices above competitive levels, and thereby earn high profits, then they invite entry.

Legal restrictions on entry, sanctioned and/or enforced by the government can be an effective barrier to the entry of serious potential competitors. Examples include import restrictions, agricultural marketing boards (which also help to solve adherence problems), or the stipulation of minimal qualifications to perform a service (requiring procedures to be performed by medical doctors, admission to the bar, etc.).

Illegal sanctions may also be available. For example, some industries dominated by organized crime may use criminal methods to deter entry. In New York garbage hauling, entrants have had their trucks blown up, or in one instance found the severed head of a dog in the mailbox of an employee. A note in the dog's mouth read "Welcome to New York." (*The Economist*, March 12, 1994, pp. 33-34.)

Undercover detectives posing as an entrant baker, Louis Basile's, in Greenwich Village were told by two members of the Association of Independent Bakers and Distributors of Italian Bread "that violence could come to Basile's and its employees if they did not play by association rules. The rules involved fixed prices for bread and a system of distribution that forced a store to buy from a single baker ... If a store wanted to shift to another baker, the association had to be consulted, and cash paid to the former baker." Basile's bought their bread at retail prices in New Jersey, and yet turned a profit for the police. (*New York Times*, July 14, 1994.)

Another possible response to entry is predatory pricing. Incumbent firms may charge low prices expressly to drive out entrants, and plan to raise prices after exit is induced. There is a literature that discusses how to determine whether prices are predatory, or merely a normal competitive reaction to entry and increased competition. Burns (1986) and Weiman and Levin (1994) describe instances in which American Tobacco and Southern Bell Telephone, respectively, used predatory pricing in order to lower the acquisition costs of competitors, in the course of building a trust at the turn of the last century. In the case of Southern Bell, predatory pricing was also used to deprive rivals of the cash flow necessary to fund expansion, thereby limiting the size of firms that remained independent. Scott Morton (1997) describes British shipping cartels in the period 1879-1929, in which some instances of entry were combated with predatory pricing whereas

other entrants were admitted to the cartel. Predatory pricing was more likely the weaker the entrant, where weakness derived from inexperience, a small scale of operations, or shallow pockets.

If there is entry, and the entrants are not party to the collusive agreement, then the non-inclusive nature of the cartel may lead to evidence of its existence. A non-inclusive cartel can be easier to detect, as outsiders can serve as a standard of comparison. As noted above, Porter and Zona distinguish complementary bids by a ring from non-winning bids submitted by the competitive fringe. Bajari and Yi (2003) describe a related method, in which participation in a bidding ring by a subset of bidders results in bidding strategies not being exchangeable, conditional on observable characteristics of the firms and the contract being allocated. That is, the presence of the ring induces a strategic asymmetry across bidders, as ring members bid less aggressively than non-members. Note, however, that such a pattern might also be attributable to unobservable firm heterogeneities in cost, as firms bid more if they have higher costs. The issue is then whether there is any plausible omitted cost factor that could account for bidding differences.

Porter and Zona (1999) provide evidence that the bidding behavior of some Ohio dairies for school milk contracts in the 1980s was more consistent with collusion than with competition. For example, several of the dairies exhibit patterns of both local and distant bid submissions. That is, they submit bids relatively near their plants and they also submit bids well beyond their local territories. Our econometric analysis of bidding levels shows that the distant bids by the three Cincinnati dairies tend to be relatively low. In contrast, other dairies' bids are an increasing function of the distance from the school district to the firm's nearest plant. These features of bidding are consistent with territorial allocation of nearby school districts by dairies with plants in the Cincinnati area to restrict competition, and relatively competitive bidding at more distant locations, which were

perhaps outside the area of territorial allocation. If bidding for local districts had been competitive, local bids should have been lower than distant bids, because shipping costs were lower and because the Cincinnati area had three potential local suppliers. The relationship between bidding behavior and distance is notable, because processed milk is relatively expensive to ship (its value is low relative to weight), and therefore competition is localized. The effect of collusion is to relax a constraint on bids by removing marginal rivals. Bid patterns reflected an “inverted price umbrella,” consistent with local market power in Cincinnati, constrained only by competition from distant rivals.

Another auction example is described by Hendricks and Porter (1988) in our study of drainage auctions. An oil or gas lease is said to be a drainage lease if there has been prior exploration in the area. In that instance, the firms with prior drilling experience will have an informational advantage over firms that have access only to seismic data. In the offshore oil and gas drainage auctions, the identities of the firms owning the mineral rights on neighboring tracts (“neighbors”) are known, and their numbers limited by the number of tracts previously sold and explored. Neighbors can gain from coordination, and they do not have to worry about non-neighbor entry dissipating all of the gains. We find that neighbors earn high profits, whereas non-neighbors approximately break even. Despite relatively high overall returns, there is less entry (i.e., fewer bids are submitted per tract) than on wildcat leases, where bidders share similar information sources. The lower entry rates on drainage leases are consistent with asymmetries of information acting as an entry barrier.

If neighbors bid non-cooperatively in the drainage auctions, then there should not be entry by non-neighboring firms, because the latter do not have access to private drilling information. Yet there is entry by non-neighbors. Further, non-neighbors’ bids are independent of the number of

neighboring firms, rather than a decreasing function as winner's curse considerations would dictate. In addition, there are often multiple bids from the neighbors on a single drainage tract, yet their ex post returns are an increasing function of the number of their bids submitted. Finally, the highest neighbor bid is independent of the number of neighbors, and their average bid level is a decreasing function of this number. This latter fact is consistent with the neighbors submitting only one serious bid, and the probability of submitting complementary bids being an increasing function of the number of neighboring leases in order to create the appearance of competition.

Problem Four: Reconciliation of Disparate Interests

Cartels often experience internal political problems. An important feature of many collusive agreements, and a determinant of their success, is the need to reconcile disparate interests. Interests may differ for a number of reasons. Firms may have adopted technologies of differing vintages for historical reasons, they may serve non-overlapping and heterogeneous customer bases, or their payoffs may be subject to imperfectly correlated shocks.

The parties to an agreement may differ on what price to charge. For example, their costs may differ. Alternatively, they may differ in their needs for immediate revenues (as in OPEC, for example), so that their intertemporal discount rates differ. Side payments could solve these problems, but they may not be legal. An unhappy conspirator whose loyalty cannot be purchased is more likely to report the collusion to antitrust authorities. In addition, the contractual terms associated with side payments may not be enforceable.

The Cave and Salant (1987) study of U.S. agricultural marketing agreements demonstrates that even legal cartels may be unable to achieve joint profit maximization, despite having broad

powers to exclude potential entrants and to punish members who produce too much. They show that voting within the cartel typically pits smaller members against larger ones, when size differences reflect underlying disparities in costs or capacities. (Cave and Salant (1995) provide a more detailed theoretical discussion.) Similarly, Hoffman and Libecap (1994) argue that differences between California and Florida growers were an impediment to collusion among orange growers in the 1930s. In a related vein, Wiggins and Libecap (1985) describe how asymmetric information can disrupt coordination efforts, using the example of oil field unitization agreements.

Levenstein (1994) describes the bromine industry from 1885 to 1914, which was dominated by American and German producers, with the Dow Chemical Company the largest. There were six price wars in this period, and most (and the most severe) appear to have resulted from disagreements over the division of spoils. There were inherent conflicts between the bromine producers because Dow had much lower costs than its rivals.

A cartel's problem is to devise a mechanism to divide the spoils and to allocate market shares. In doing so, the cartel may have to overcome an adverse selection problem. If the conspirators have private information concerning demand or their own costs, then each member will argue for a bigger share of the spoils. An efficient cartel solution will maximize cartel profits, subject to participation and information revelation constraints.

An imperfect but simple solution to the cartel problem assigns customers or territories to the participants, and then grants individual firms wide latitude within their own territories. In the case of bromine, Dow and the German combine agreed in the early 1900s to stay out of each others markets (although Dow secretly exported to Europe, and a couple of mild price wars occurred as a result of the ensuing disputes).

A territorial assignment could also be temporal, if firms take turns winning contracts, say via a rotating bidding arrangement. An extreme example occurred in the 1950s, when General Electric and Westinghouse assigned low bid privileges for electrical equipment contracts based on a phases-of-the-moon system (Smith 1961). Costs differences between the firms are unlikely to account for this bidding pattern.

More typical are the New York trash haulers, whose associations

carved up the city, using a system of “property rights” ... Each carting company “owns” buildings where their customers are located. If a company that is not a member of the trade associations tries to offer a lower price for a building’s business, the associations scare off the interloper with arson and physical violence ... If a company inside the cartel takes a site away from another hauler in the cartel, ... the associations force the offending company to pay the old carter up to forty times the monthly pickup charge. ... [An] undercover police detective posing as a carting executive paid more than \$790,000 in “dues” to the associations and in compensation to other carters. In exchange, he won the right to pick up garbage at stops where he had submitted the lowest bid. (*New York Times*, June 23, 1995.)

Cramton and Schwartz (2000) argue that some bidders in the C block FCC spectrum auctions achieved a territorial division by using trailing digits on their bids to signal their interest in acquiring specific licenses, and how they intended to retaliate should anyone encroach on their territory. The FCC simultaneous ascending auction procedure kept bidding open on all licenses throughout the auction, and firms with enough eligibility could switch between licenses. Some bidders used trailing digits to communicate their intentions. For example, one response to a new bidder in one’s territory was to outbid that firm on at least one other license where it held the standing high bid. The response bid’s last three digits would be the identifying code of the original market, and the intended message was the offer to not compete if they stay out of your territory. No overt communication is involved, unless the parties need to resolve how to interpret bid signals, and a territorial allocation could be achieved at relatively low bids. The auction rules could be amended to prevent this sort of signaling,

for example by requiring new bids to be a fixed amount or fraction higher than the current high bid. There could also be a fixed ending time to the auction, in which case it would not be possible to retaliate after that time.

Another imperfect solution is to maintain stable market shares. Pesendorfer (2000) argues that a weak conspiracy that cannot make side payments may be forced to maintain relatively constant market shares, despite some losses from not allocating bidding rights to the low cost firm, in order to maintain internal discipline. He shows that, if there are many items being sold, the ring can achieve approximate efficiency via a ranking mechanism. That is, members rank items, and contracts are assigned on that basis. The ring does not achieve full efficiency, as minimal market shares must be guaranteed to ensure that participation constraints are satisfied. He compares Florida and Texas bid rigging schemes for providing school milk, and shows that market shares were less stable in Florida, where the dairies used side payments.

The constancy of market shares and geographical specialization, while consistent with a collusive assignment, are not in and of themselves evidence of collusion. There is a tendency to view bid rotation or incumbency advantages as evidence of presence of collusion. Under a rotating bid arrangement, firms take turns submitting “serious” bids for the ring. However, these patterns can be consistent with non-cooperative bidding. For example, bid rotation is a natural outcome in auctions of highway construction contracts where bidders’ cost functions exhibit decreasing returns to scale. Firms with idle capacity are more likely to win a contract, but having won the contract, are less likely to win another until some existing contracts are completed (Porter and Zona, 1993).

Similarly, patterns reflecting incumbent advantage can reflect unobserved asymmetries among firms. Those who won contracts or customers in the past may have done so because of

location or other advantages that persist through time. Incumbents may have the advantage of lower costs due to experience, or an advantage with buyers who are reluctant to switch suppliers. An empirical challenge is to develop tests that can discriminate between collusive and non-cooperative explanations for rotation or incumbency patterns.

Collusion is frequently observed in private value auctions where bidders differ in their idiosyncratic willingness to pay, as opposed to differences in information concerning common components of valuations. Examples include highway construction contracts (Porter and Zona, 1993), school milk delivery (Pesendorfer, 2000; Porter and Zona, 1999), and timber auctions (Baldwin et. al., 1997). In each of these examples, the heterogeneity in bidder valuations is due primarily to differences in costs that are arguably idiosyncratic to each bidder. The cartel's problem is to devise a mechanism to divide the spoils and select who is going to bid for the contract.

Conspirators in auction markets often assign one firm to represent the ring in the bidding in a separate knockout auction among the group before the seller's auction (Graham and Marshall, 1987). In a prior knockout auction, the ring members bid for the right to be the sole bidder in the seller's auction. The bidder who bids the highest amount wins this right, and the winner pays an amount to the other bidders based on the bids submitted. If the seller knows that a knockout auction has preceded the sale, it should set a higher reserve price. Therefore, it is in the interest of the ring to keep its meeting secret. According to Preston McAfee, one conspiracy was investigated by the U.S. Department of Justice after a bidder submitted an envelope containing his own bid plus his notes from a pre-auction meeting.

If an all-inclusive cartel uses side payments, it can design a pre-sale auction knockout to induce each member to reveal their private valuations, and to achieve full efficiency by awarding the

item to the member who has the highest valuation (Graham and Marshall, 1987; Mailath and Zemsky, 1991; and McAfee and McMillan, 1992). Furthermore, each cartel member's expected payment exceeds the payoff from non-cooperative bidding. Consequently, the bidders prefer the cartel mechanism to bidding non-cooperatively in the seller's auction. Moreover, the mechanism can achieve a balanced budget ex post, so that external financing is not required.

Most early studies identified behavior that is difficult to reconcile with a non-cooperative bidding. An extreme example involves the submission of several identical bids. Mund (1960) and Comanor and Schankerman (1976) describe several instances of identical bids "independently" submitted in government procurement auctions. In 1955, five companies submitted identical sealed bids of \$108,222.58 for an order of 5,640 one hundred capsule bottles of antibiotic tetracycline (Scherer and Ross, 1990, p. 267). The submission of many identical bids is an unlikely non-cooperative equilibrium if there are any differences in information or valuations across bidders. But such behavior can be an optimal allocation mechanism for weak cartels when valuation differences reflect idiosyncratic factors. McAfee and McMillan (1992) show that it may be optimal for a weak cartel (that is, one that cannot make side payments) to submit many identical bids at the reserve price, and rely on the auctioneer to randomly select among them.

An alternative to a pre-sale knockout auction is a post-sale knockout, such as the one used by a bidding ring involving rare book dealers in England circa 1900. After one large estate sale, the ring held a series of knockout auctions. Successively smaller subsets of the dealers conspired to deprive the seller, and then their fellow conspirators, of some of the gains. The book dealers differed according to experience and scale of operation, and the larger and more experienced dealers stayed longer in the knockout process. The participants in the various knockout auctions shared the price

increases over prices in the previous round. The original seller received less than 20 percent of the final settlement prices. (Note that knockout prices should advance beyond willingness to pay, because of the sharing of price gains above the previous round. Therefore the 20 percent figure probably overstates the damages to the original seller from the conspiracy.) Why did the larger ring members conspire with the smaller members? If they had not, the larger dealers would have had to outbid the smaller dealers at the original auction, and it would be cheaper to share some of the gains with them. But it is also in their interest to share only enough to buy the loyalty of the smaller dealers, and not the full difference between the original purchase price and what the larger dealers were willing to pay. (Porter (1992) provides a brief account.)

If the bidders know that they share common valuations, a bidding ring's internal allocation problem is much simpler. The designation of the bidding representative does not matter if all members value the item identically. In these situations, bidding rings can adopt division rules in which all members share equally in the spoils. Given this sharing rule, cartel members have no incentive to misrepresent their information. They share a common goal, which is to bid only when the expected value of the item conditional on the pooled information exceeds the reserve price. The problem with such agreements, however, is that the expected payment to cartel members may not exceed the amounts they can expect to earn (conditional on their information) by bidding alone in the seller's auction. A bidder who has favorable information when commonly available signals are pessimistic may be able to win the lease by bidding slightly above the reserve price. There will be a somewhat higher price paid to the seller, but the surplus is not shared with other firms. More generally, Hendricks, Porter, and Tan (2003) show that an efficient cartel mechanism may not exist under these circumstances. If there is uncertainty about whether the ring should bid, there is option

value from participating in the knockout auction and learning others' signals. Bidding may then be more aggressive in the knockout auction than in the non-cooperative equilibrium of the primary auction.

A bidding ring in a common value auction may also have to worry about a moral hazard problem. Each member has an incentive to free ride on the information gathering activities of other members. These difficulties may explain why collusion appears to be less frequent in common value environments than in environments where bidders' intrinsic valuations differ.

This intuition may explain the surprisingly low incidence of joint bidding among firms with the highest participation rates in federal offshore oil and gas lease auctions. Solo bidding and joint bids with smaller firms were the dominant form of bidding for the most active participants. Joint bids involving more than one of these twelve firms represented less than 20% of all their bids. Furthermore, if these firms bid jointly, they did so almost always in pairs.

However, solo bidding does not imply the absence of collusion. In testimony before Congress in the mid 1970s, Darius Gaskins of the Department of Interior argued that the collusive effects of joint ventures should not be measured solely in terms of tracts receiving joint bids. The negotiations to bid jointly could allow partners to coordinate their solo bids. The cartel could, for example, hold a first-price knockout tournament on each tract in a specific area to determine who valued which tracts more highly than others, and allocate the tracts accordingly. If this allocation does not achieve an equitable balance among its members, firms with larger allocations could agree to bear a larger share of the costs of drilling the area or, if oil is discovered and the area unitized, a smaller share of production. Mechanisms involving side payments could give optimistic bidders a stronger incentive to participate. The potential gains from forming a cartel appear to be substantial.

The stakes are large, and the risks significant. By pooling geological data and expertise in interpreting the data, firms could reduce the risk of buying dry leases and, by pooling financial resources, they can bid for more leases and diversify away more of the tract-specific uncertainties.

Hendricks, Porter, and Tan (2003) study data from federal oil and gas wildcat auctions off the coasts of Texas and Louisiana. We document a positive correlation between the incidence of joint bidding and the value of tracts. This correlation may reflect the incentive for firms to find financial partners on tracts where the winning bid is likely to be large. However, it may also reflect the adverse selection problems on low value tracts described above.

We also find evidence of bid coordination by bidders who bid jointly in a sale. In particular, bidders almost never submit competing solo bids if they have submitted a joint bid in a nearby location in the same sale. Joint bidding negotiations appear to cover tracts in areas of common exploration, as opposed to specific tracts.

Problem Five: Responding to New Circumstances

As costs or market demand changes, a cartel may want to adjust the agreed-upon prices or allocation rules. Genesove and Mullin (2001) document how the Sugar Institute continually updated the agreement with respect to the terms and conditions of market transactions.

But how can changes be coordinated if firms cannot communicate? One solution is to designate a price leader. For example, the leader could announce a price increase thirty days in advance, where the increase would be implemented only if its rivals then announced that they would follow. Advance notices can be a substitute for formal meetings, which may be illegal or costly to arrange. They also ensure some degree of unanimity, and as such are a crude form of voting. Grether

and Plott (1984) argue that advance price announcements facilitated collusion in the ethyl market in the U.S. in the 1970s, and present some corroborating experimental results. Holt and Scheffman (1987) provide theoretical support for Grether and Plott's interpretation.

More generally, how prices respond to demand or cost changes can differ for competitive and collusive industries. One might be able to distinguish between competitive and collusive behavior by looking at prices and market shares before and after a merger or a plant closing, say. Without such changes, it is difficult to tell whether all firms charging the same price is consistent with collusion or competition.

Collusive behavior may arise in a variety of environments, supported by one of a number of facilitating practices. Furthermore, concentration indices may not be helpful in determining when monopoly rents are being earned. For example, if a naturally monopolistic market is contestable, in the sense that costs are not sunk and entry can occur relatively costlessly in a short period of time, then an incumbent monopolist may be constrained by potential entry to price at average cost. Alternatively, if two firms with identical constant unit costs and identical products set prices non-cooperatively in a one-shot market game, then, absent any threat of entry, they will earn zero profits. On the other hand, if a large number of firms interact perpetually, as in a supergame, then by appropriately designing retaliatory strategies in response to observed defections, the firms can charge monopoly prices and so collude in a non-cooperatively viable manner, as long as future profits are not discounted too much. Thus antitrust intervention solely on the basis of market share distributions may be misguided, as high concentration indices are neither necessary nor sufficient for collusion to be successful, or for monopoly rents to exist.

As a result, an important role for empirical work is to discriminate between different behavioral theories, and so to identify noncompetitive industries. This is possible only if the theories in question have qualitatively different comparative statics implications. Bresnahan (1989) surveys techniques of measuring the extent of market power of individual firms, or a group of firms, in a given industry.

One form of comparative static is the effect of ownership patterns on prices. Bresnahan (1987) examines the US automobile industry in the mid 1950s. He can distinguish between collusive and non-cooperative pricing because individual firms sold several different models. Non-cooperative prices depend on whether nearby products (in characteristics space, appropriately defined) are owned by rival firms, whereas joint profit maximizing prices do not.

Haltiwanger and Harrington (1991) describe dynamic pricing under a cooperative scheme where demand fluctuates over time. For example, suppose that demand follows a predictable seasonal pattern. Then the incentives to cheat on an agreement to charge monopoly prices will follow the cyclical pattern of demand, for the gains to cheating are proportional to the level of demand. But the costs associated with a collapse in the agreement are counter-cyclical. For example, at the peak of the cycle, the conspirators know that demand will be lower in the near future, and the consequences of a collapse are less dire. As a result, the conspiracy may charge prices that lead the cycle, in the sense that the most profitable prices that are immune from cheating should decline before demand does. For a given level of demand, prices should be higher when demand is increasing than when it is decreasing, as the losses from the collapse of the agreement are more severe. Borenstein and Shepard (1996) find evidence of this sort of a seasonal pattern in retail gasoline markets in U.S. cities.

An Open Issue

Arguably, illegal agreements are distinguished by communication. A cornerstone of antitrust law is the per se illegality of pricing negotiations, whether or not they result in higher prices. But what is the role of communication? In a legal cartel with side payments, communication may be in the spirit of the mechanism design literature, in which allocations and payments are functions of internal messages. But communication also plays a role in dispute mediation, and more general design of rules, contracts and institutions. Genesove and Mullin's (2001) study of the Sugar Institute is instructive in this regard.

Absent the ability to write binding contracts, there are other roles that communication can play. For example, in a repeated game, communication affects renegotiation after disruptions. Thus communication may affect the severity of punishments, especially if punishment entails collective sacrifice. McCutcheon (1997) and Farrell (2000) show that limiting renegotiation opportunities can result in more collusive outcomes. Of course, negotiations may also facilitate reaching an initial agreement.

The outstanding issue is that we do not fully understand how communication affects market outcomes. Whinston (2004) therefore asks whether it is obvious that per se prohibition is socially beneficial.

Acknowledgements

This paper was prepared for a keynote address for the 2004 International Industrial Organization Conference in Chicago. This material also formed the basis of the 2003 Leverhulme Lecture at the University of Warwick, the 2004 Rogers Clark Lecture at North Carolina State University, and a talk at the 2004 Roundtable on Tacit Collusion sponsored by the Canadian Competition Bureau. I am grateful to the National Science Foundation for financial support, and to Chris Snyder for his comments.

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