Introduction

At least since the time of Adam Smith (1776), economists have believed that sellers are likely to discuss common price strategies, but that incentives to defect may be strong enough to break down collusive agreements. Collusion is difficult to study in naturally occurring markets, since sellers will try to hide illegal activities from buyers and from antitrust authorities. Even when a conspiracy can be established, the effective dates, the exact identities of all participants, and the real effects on prices are typically difficult to prove. In particular, price-fixing may result in stable common prices, but it is usually impossible to say what prices would have been without collusion, at least in the absence of precise cost and demand conditions. Even when markets seem to alternate between collusive and non-collusive phases, the price differences are difficult to interpret since a breakdown in collusion may be caused by a demand decrease that would have reduced prices in any case. This makes the laboratory an ideal setting to study factors that facilitate or hinder illegal price fixing.

The main result from the experimental economics literature is that the market trading institutions are crucial in determining whether or not collusion will be successful in raising prices above competitive levels. The initial paper on this topic was Isaac and Plott (1981), who examined the effects of seller discussions between rounds of a continuous double auction. In particular, (???a subset of) the sellers were allowed to come together to a corner of one of the rooms and confer after the close of one trading period and before the start of another. Attempts to collude were as ineffective as they were inevitable. The problem is that each seller has a strong private incentive to defect and lower the asking price during the course of the double auction trading (Clauser and Plott, 1993).

In some sense, the Isaac and Plott (1981) result is consistent with Smith's (1981) finding that even a single-seller monopolist could not always find and enforce near-monopoly prices when

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trading with a number of buyers in a continuous double auction. Smith, however, did observe consistent supra-competitive prices, sometimes approaching monopoly levels, in posted-offer monopolies with the same supply-and-demand design. The posted-offer trading rules preclude price cuts during the course of the trading, which facilitates monopoly pricing. This raises the issue of what would happen in a posted-offer conspiracy with more than one seller. Isaac, Ramey, and Williams (1984) addressed this issue and found that sellers were much more effective when conspiring about prices that were posted on a take-it-or-leave-it basis.

Many markets of interest to industrial organization economists do not fit exactly into the double-auction or posted-offer category. Sometimes sellers post list prices, for example, and then consider offering discounts if sales are falling behind expectations or if there is other evidence that others are offering secret discounts. The next section summarizes some experiments that illustrate the dramatic effects of opportunities to collude without discounts, and the opportunities to offer secret discounts even if there is collusion. Then the effects of collusion in some other auction and securities market trading institutions are considered in the final section.

Collusion with and without Secret Discounts

The dramatic effects of conspiracy in a posted-offer auction are shown in Figure 1, which summarizes two sessions reported in Davis and Holt (1998). There were six subjects in each session, randomly assigned to the three buyer and seller roles. Subjects were visually isolated and interacted over a network of personal computers. The supply and demand arrays are reproduced on the left side of the figure, and the theoretical competitive and joint-profit maximizing prices are indicated by horizontal dashed lines.

First look at the green series for the standard posted offer market without collusion. The posted prices for the three sellers are indicated by small circles, and contracts (units actually sold) are shown as dots to the right of the corresponding circle. The price data for each period are separated by vertical lines, with the period number (from 1 to 15) shown at the bottom. Within the slot for each period, the price for seller S1 is plotted to the left, the price for S2 in the middle, and the price for seller S3 is on the right. Thus the blue circle for seller 1 in the first period is above the
monopoly price (sellers were not given information about the demand curve or others' costs). Seller S2 has the low price in period 1, as shown by the blue circle with the three dots that indicate sale of three units. By the third period, all sellers' prices are nearing competitive levels, and the average price actually falls somewhat below the highest competitive price in periods 6 to 13. As intended, this is a very competitive supply and demand design.

The upper red price sequence in Figure 1 shows a parallel session in which price collusion among sellers was permitted prior to the start of each period. Buyers were taken from the room under the guise of using a random device to assign them to buyer roles, B1, B2, or B3. As buyers entered the hall to return, an experimenter alerted the sellers, who ceased discussions and slid their chairs back into their visually isolated booths before entering their prices for the next period. After some initial bouncing around in early periods, sellers agreed on a common price in period 5, but all three buyers purchased from seller S1, which may be due to the focalness of the "1" key, despite the fact that this seller had been offering higher prices in earlier periods. Seller 1 then suggested a price rotation scheme, with him going first! Incredibly enough, the other agreed, and S1 sold all three units at a price slightly below the others, as indicated by the red dots attached to the left-hand circle in the period 6 slot. This "phases-of-the-moon" rotation continued, as the sellers experimented with different prices over the next several periods. Prices were raised above the joint monopoly level in period 9, which resulted in only two units sold, and sellers returned to an exact monopoly outcome in period 10. The price reduction experiment in period 12 did not increase sales, so prices returned to near-monopoly levels for the final rounds. The industry cost structure was such that this rotation is very inefficient, since each seller had a low-cost unit, but only one of these would get produced and sold under price rotation. Interestingly, sellers moved to the more profitable equal-division arrangement in period 15, even though they had no way of knowing that was the final period.

The pattern effects of collusion in Figure 1 were replicated and were significant using a non-parametric test applied to the session price averages. A particularly interesting collusion

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1 Here we see one of the advantages of using human buyers, since simulations may introduce too much uniformity or too much randomness relative to human behavior.

2 The defendants in the celebrated electrical equipment price-fixing case of the early sixties had used phases of the moon
session is plotted by the red sequence at the top of Figure 2. As before, there is some price variation in the initial periods before a common price is established in period 4. Seller 2, however, does not sell anything, and they then agree to limit sales to one unit each in an effort to solve the "random selection problem." This split is honored in the next period, but the agreement breaks down as seller two prices aggressively in periods 8 and 9, thereby making all of the sales. In period 10 sellers finally coordinate a uniform, high price. Despite the fact that there was an understanding that each would limit sales to one unit, S2 cheated and sold two units, as indicated by the two dots attached to the middle circle for that period. Seller S3 was "not happy," but S2 covered up the defection by claiming that they should have expected sales to be lower when price is higher. Whether believed or not, this deceptive claim let them to agree on a uniform price reduction, with equal splits being honored in periods 11 and 12. They decided to try another increase in period 13, and seller 2 defected again, and again claimed deceptively that the failure of S3 to sell a unit was due to the demand reduction at a higher price. This only resulted in a slight price decline, with high prices and efficient market splitting the rule in the final two periods.

The next issue is the effect of opportunities to offer secret discounts from list prices that come out of a conspiracy. The setup for these "list-discount" sessions was the same as before, with the buyers being taken from the room while (without their knowledge) sellers discussed prices. The sellers then returned to their personal computers and entered their prices as buyers returned to the room. The main difference between this treatment and the previous conspiracy setup is that buyers could select a seller and direct a discount request to that seller by pressing a specific key. The seller selected would respond by typing in the original price or a lower one. Other sellers could not tell by the number of keystrokes whether the response was a discount or not. A buyer who was not satisfied with the seller's response could switch to another seller, which resulted in a "switching cost" of 5 cents that was deducted from the buyer's earnings for each switch (see Davis and Holt, 1998, for details).

The price data for a typical session with discounting is shown in green in the lower part of

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3 To ensure comparability across treatments, this switching cost was assessed in each of the other treatments as well.
figure 2. When a discount price is accepted, the dot indicating that sale may lie below the green circle directly above, which marks the seller's list price. The opportunity to discount clearly causes a breakdown in the effectiveness of the conspiracy, but the breakdown process is particularly interesting. As in the previously discussed collusion sessions, there is considerable price variation in the initial period before a common price is selected in period 3. Seller 2 sells nothing, however, so they agree to a price reduction at which all sell at least one unit in period 4. This success emboldens them to raise prices. The prospects for high earnings start to fade when seller 2 discounts from the common list price in periods 6-8. Notice that these are not small discounts, indicating that seller 2 is suspicious that the others may do the same. Seller 1, who sells nothing in periods 7 and 8, offers a deep discount in period 9 and defects from the list price agreement in period 10. This results in persistent discounts for the remaining periods, despite the fact that sellers are able to agree on a common list price. Finally, note that the price fixed in these final periods was only slightly above competitive levels.

The next issue considered was whether providing more information to sellers about market shares may facilitate collusion, even in the presence of discounting. In particular, we ran a parallel series of sessions in which we provided ex post sales quantity information to each seller. This information, which is of the type sometimes disseminated by a trade association, makes it possible for sellers to monitor sales quantity agreements. In fact, this type of sales information did result in price increases: prices in the conspiracy/discounting/sales-information sessions were about halfway between the low prices for the conspiracy/discount treatment and the high prices for the conspiracy/no-discount treatment.

The conclusion emerging from these and other sessions is that seller conspiracies can raise prices to near-monopoly levels, even in environments that yield competitive prices in a standard posted offer market. Second, this success of this price-fixing tends to evaporate when colluding sellers are given the chance offer secret discounts to individual buyers. This research suggests that antitrust hostility to contracts and codes that impede or discourage price discounts is justified. Moreover, it is now known that contracts which reduce sellers' flexibility to offer buyer-specific discounts may have the effect of raising prices, even in the absence of explicit collusion (Grether and Plott, 1984).
Recent Work

Cason (1997) examines collusion among subjects who are put into the position of serving as dealers in asset markets. Pricing was competitive and efficiency was high in most sessions without collusion. When given the chance to discuss point spreads, the dealers were able to widen the spreads. Cason concludes that the screen trading system facilitated collusion by making it easier to spot defectors.

One key issue in the study of collusion is how to infer whether or not it exists, since as seen above, colluding sellers may fix a near-competitive price (Figure 2), or non-colluding sellers may lock onto a common competitive price (Figure 1). Davis (1998) addresses this issue by letting sellers' costs be determined by whether how much idle capacity they have. For example, a highway construction contractor with lots of current jobs may have high costs if adding another job requires new hiring and equipment purchases. Thus cost differences are endogenous, with winning bidders in one auction becoming high-cost bidders in the next. The work of Porter and Zona (1993) suggests that collusion will reduce the correlation between the bid amounts and costs of colluding bidders who agree to bid above one of their co-conspirators.

Thusfar, our focus has been exclusively on verbal forms of collusion. The rise in the use of computerized auction and sales systems opens up the opportunity for a number of near-collusive types of signals. For example, bidders in the recent Federal Communications Commission bandwidth auctions used decimal bids to identify zip codes, and airlines sometimes attached letter combinations (e.g. FU) to fares that seemed to send particular messages. Some of the bids even had explicit phrases attached. The effects of such procedures is examined by Cason and Davis (1995). The laboratory evidence reviewed here suggests that such non-verbal methods of communication will be more effective when prices are posted on a take-it-or-leave-it basis.
References


Red markers indicate the series of price postings (circles) and contracts (dots) for a collusive session, without discounting possibilities.

Starting in period 5, a "phases of the moon" price rotation scheme, indicated by the rotation of contracts (dots) across periods.

Blue markers indicate the series of price postings (circles) and contracts (dots) for a standard posted offer market, with no collusive opportunities.

Figure 1
Green markers indicate the series of price postings (circles) and contracts (dots) for a market with collusive opportunities, but also with private discounting.

Red markers indicate the series of price postings (circles) and contracts (dots) for a second collusive session, without discounting.

Contracts (dots) below postings (circles) indicate that discounts were granted.

Figure 2