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Price Communications in a Multi-Market Context: An Experimental Investigation

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Abstract. This experiment assesses the effects of nonbinding price communications in a multi-market, posted-offer environment. In half of the ten sessions, three symmetric sellers continuously submitted nonbinding prices for two minutes prior to posting final binding prices. In the remaining sessions sellers posted only binding prices. Competitive prices were observed infrequently in either treatment, but prices were persistently higher when communications were possible. The way that communications affect performance is unclear. With or without communications, high prices appear to be more a consequence of some sellers supporting the defections of others, than of a developed "language of conspiracy."

Key words: Airline competition, experimental economics, multimarket competition, nonbinding communications.

I. Introduction

Adam Smith's legendary observation that "sellers of the same trade seldom meet together . . . but the conversation ends in a conspiracy against the public . . . " enjoys broad if not nearly universal consensus among economists.[1] Much more divisive is the related issue of what constitutes a "meeting." Clearly, the specter of conspirators murmuring in a smoke-filled room conjures an image of illegality. But sellers also inevitably and routinely communicate every day, in the open air, and in ways that are perfectly innocuous. Indeed, any advertised sale is a communication both to other sellers and to potential customers, and a rival's competitive reaction is typically regarded as a socially desirable communicative response.

Of course, conspiracies may evolve under the most spartan of circumstances, e.g., even when seller communications are confined to public price quotes. But a

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[1] Smith (1776, p. 128).

variety of ancillary modes of communication may facilitate cooperation. Sellers, for example, may attempt to signal cooperative intentions by sending nonbinding price signals through articles in trade press publications. Such communications have not typically been regarded as illegal.[2] However, recent developments in the technology of price-sharing have pushed to new limits the speed with which sellers can send and respond to such signals.

One particularly controversial pricing mechanism is found in the airline industry, where sellers post prices through an Airline Tariff Publishing (ATP) system. This electronic system allows sellers to modify prices rapidly and at very low cost. Prior to an antitrust action against the ATP settled in early 1994, airlines could also send and respond to an unlimited number of nonbinding price announcements, by proposing prices with effective dates ("first ticket dates") in the future. The airlines were also accused of suggesting the removal of pricing actions they do not favor with similar fares that had withdrawal dates ("last ticket dates") only a few days in the future.[3]

As a general matter, consumers stand to gain from extra price information. Announcements of future prices, for example, may benefit consumers, by allowing them to more readily take advantage of sales. Such announcements, however, are also a potentially rich form of "cheap talk," which sellers may use to organize collusive outcomes.[4] The technical capacity of firms to broadcast and revise price quotes almost instantly raises anew the antitrust policy question of what modes of indirect communication allow sellers to develop an effective language of cooperation. This question's resolution is unlikely to be unidimensional, as the coordinating capability of different modes of communications is quite likely affected by the underlying market structure. Remarkably insightful analysis regarding the success of con-

[2] Although explicit price-fixing agreements are illegal *per se* under Section 1 of the Sherman Act, alleged tacit collusion through price-sharing is subject to the *rule of reason*. Relevant cases have focused on the informative versus conspiratorial functions of price-sharing, and courts have examined the purpose and effect of price-sharing programs as well as the related conduct of participating firms [see *United States v. Container Corp. of America*, 393 U.S. 333 (1969)]. Price sharing, and related activities have been viewed as illegal '[W]here the circumstances are such as to warrant a jury in finding that the conspirators had a unity of purpose or a common design and understanding, or a meeting of minds in an unlawful arrangement..." *American Tobacco Co. v. United States*, 328 U.S. 781 809–810(1946). The issue that stimulates our research is the extent to which recent developments in the technology of price-sharing can effect such a "meeting of the minds."

[3] *United States v. Airline Tariff Publishing Company et al.*, Civil Action No. 92–2854, original complaint filed December, 1992. For an easily accessible summary of the case and settlement see *Antitrust and Trade Regulation Report*, March 17, 1994, pp. 309–310.

[4] Farrell (1987) provides a game-theoretic motivation for the coordinating influence of "cheap talk" in a battle-of-the-sexes game. The idea is that if nonbinding signals are taken as informative, they may be used to eliminate "off-diagonal" disequilibrium outcomes. Results of an experiment involving cheap talk in a battle-of-the-sexes games reported by Cooper, DeJong, Forsythe and Ross (1989) indicate that nonbinding communications can reduce the incidence of disequilibrium outcomes. It is important to observe, however, that the potential role of "cheap talk" as a collusive device can be rather distinct from its role as a coordinating device. In the case of collusion, one dynamic equilibrium may Pareto dominate all others, and the primary function of nonbinding communications may be to clarify the intended plays and responses that guide players to this equilibrium.

spiracies has occasionally employed naturally-occurring data (see e.g., Porter and Zona, 1993; and Porter, 1983). However, the illegality of collusion, combined with the likely interaction between communications and underlying structural elements, makes the control allowed by laboratory analysis particularly appealing.

The purpose of this paper is to examine the capacity of indirect, public communications to facilitate collusion. Specifically, we use laboratory methods to evaluate the effects of continuous nonbinding price communications on transaction prices when sellers meet simultaneously in multiple markets. We proceed as follows. Following a review of the relevant literature in section II, we discuss the experimental design in section III. Section IV presents the results, and section V follows with some closing remarks.

II. Communications, Multimarket Competition, and Conspiracy

Laboratory research suggests that the relationship between opportunities for communication and price increases is not simple. At one extreme, it is clear that direct communications can powerfully affect outcomes, particularly in retail-type "posted-offer" markets;[5] in otherwise competitive posted-offer markets with three and four sellers, face-to-face communications consistently generate joint-profit-maximizing collusive outcomes (Isaac, Ramey and Williams, 1984; Isaac and Walker, 1985; Davis and Holt, 1993b). Successful conspiracies have also been generated in duopoly contexts, via both written communications (Friedman, 1967), and anonymous but free-form computer communications (Brown-Kruse, Cronshaw and Schenk, 1993), suggesting that face-to-face contact may not be a necessary element of the direct communications.

But these agreements are not particularly resilient. Even face-to-face discussions do not generate stable conspiracies when posted-offer rules are replaced with the more interactive double-auction trading rules characterizing many financial exchanges (Isaac and Plott, 1981). Moreover, even in posted-offer markets sellers fail to generate stable conspiracies with face-to-face communications when the environment is enrichened to allow for the possibility of (nonmonitorable) opportunities for secret price discounts (Davis and Holt, 1993b).[6]

Moreover, more restricted forms of communication appear to be yet poorer mechanisms for organizing conspiracies. Holt and Davis (1990) report a only transitory effect from a very structured type of price signalling in a triopoly market.

[5] The posted-offer trading institution studied here parallels many features characterizing trade in many retail contexts, and is most appropriate for the airline application. It also has a long history in the experimental economics literature (see Davis and Holt, 1993a, ch. 4, for a survey). In this institution, sellers move first by posting take-it-or-leave-it offers. Buyers then shop among sellers and have only the ability to accept or reject the available offers.

[6] The failure of conspiracy in double-auction and in posted-offer markets with discounting opportunities are related. Clauser and Plott (1991) conclude that the continuous temptation to defect is the primary reason that conspiracies fail in double-auctions. Results of Davis and Holt (1993b) may be interpreted as extending this conclusion to a retail-type market.

In that market sellers rotated signalling roles, one posting a nonbinding price and the other sellers signalling nonbinding intentions by either agreeing or disagreeing with that price. Similarly, Cason (1995) finds no discernable effect from allowing sellers to post a single, nonbinding advance price offer, and a slightly stronger, but still weak and transitory effect from allowing sellers to submit as many nonbinding price quotes as they wish in a one-minute signalling period.[7]

The Cason investigation most closely parallels the communication structure prohibited in settlement of the federal and private suits against the airline industry. However, Cason's largely negative findings are limited for the present application because his laboratory environment excluded potentially important features of the airline industry. In particular, as is typical of most laboratory investigations, Cason confines attention to interactions in a single market. Continuous nonbinding price communications may be more effective in the multi-market environment characterizing airline competition.

Ever since Corwin Edwards (1955) proposed that the interaction of sellers in multiple markets could lead to less aggressive competition, there has been interest in the notion of "mutual forbearance." As a theoretical matter, multi-market competition can generate higher prices in a static Cournot quantity-setting world (or in a Bertrand world with differentiated products), if sellers share a positive "conjectural forbearance" parallel to the notion of a conjectural variation between rivals in a single-market setting (Feinberg and Sherman, 1985, 1988). Multi-market interaction may also raise the profitability of the maximal sustainable equilibrium in a dynamic game (Bernheim and Whinston, 1990), with the intuition being that multi-market competition allows sellers to exploit slack incentive constraints arising in the single-market context. Limited laboratory evidence suggests that each of these interactions may modestly increase collusive behavior in duopolies (Feinberg and Sherman, 1985, 1988; Phillips and Mason, 1992).

The U.S. airline industry's recent evolution into the current hub-and-spoke structure makes it a very special case of multi-market competition.[8] The combination of low-cost flights originating from each firm's hub, along with higher cost "competitive" flights for each airline, gives rivals an opportunity to send unambiguous signals. For example, Airline A may communicate displeasure with the overly competitive activities of Airline B by cutting prices in Airline B's low-cost hub markets. Since the price cut occurs only in B's low-cost market, Airline B will know that a punishment is being administered. Moreover, remaining competitors will not confuse the price cut with a defection from a collusive arrangement, since

[7] Grether and Plott (1984) observed more sizable price increases in environments which included a provision for posting advance notice of price changes. However, the advance notice provision was investigated in conjunction with other alleged collusion-facilitating practices, and the marginal effects of the advance notice provisions were not assessed.

[8] Evans and Kessides (1994) report that multimarket contact has a significant effect on airline prices, increasing average round-trip ticket fares by more than $20.

prices are not lowered in other markets.[9] Indeed, punishments of this type have been identified as a feature of airline competition. For example, Viscusi, Vernon and Harrington (1992) relate the following 1989 incident between America West and Northwest airlines.

> America West set a low fare of $258 roundtrip for the Minneapolis-Los Angeles route. This low fare would largely attract passengers from Northwest as it has a hub in Minneapolis. Rather than lowering its $308 fare to match America West, Northwest set a new fare that struck directly at America West's hub in Phoenix. Northwest cut its $208 fare between Phoenix and New York to $168 and, most interestingly, initially made the fare available for only two days. Apparently, America West got the message. Five days after setting its low Minneapolis-Los Angeles fares, America West rescinded them. (p. 122)

In this episode high prices were maintained in a multi-market context, through the "last ticket date" signalling feature of the ATP. If concerns reflected by the Department of Justice in the recent ATP suit are justified, this episode was typical, and active price-sharing communications greatly enhance opportunities for collusion.[10] Our interest is the extent to which the combination of multi-market competition and nonbinding price communications allow sellers to coordinate effective conspiracies.

III. Experiment Design

The experiment consisted of a series of ten sessions. In each session, three sellers, "S1," "S2" and "S3" simultaneously competed in three markets, "Market 1," "Market 2," and "Market 3." Supply and demand arrays for each market are shown in Figure 1. As is evident from the seller identities printed below the cost steps, the sellers are symmetric in the sense that each has a single "low-cost" market, where they have 2 units at a cost of 100 each, and two "higher-cost" markets, where they have one unit that costs 100 and a second unit that costs 150. For example, as indicated by the bold "S1" markings in Figure 1, Market 1 is seller S1's low cost market, and seller S1 may offer one low cost and one high cost unit in markets 2 and 3.

All markets were conducted under posted-offer rules: At the beginning of each period, sellers were endowed with units and then privately made price/quantity decisions in each market. After all prices were posted a simulated, fully revealing

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[9] Beil (1988) argues that the inability to offer firm-specific punishments is a primary complication for collusion when more than two competitors are involved. Beil supports this argument with the results of an experiment involving a series of quantity-setting quadropolies, some of whom are given the option to deliver "specific punishments."

[10] The Department of Justice complaint alleges that the airlines "traded fare increases or the elimination of discounts in one or more city-pair markets for fare increases or the elimination of discounts in other city-pair markets." They claim to have identified over 50 such price-fixing agreements, affecting hundreds of city-pair markets [*United States v. Airline Tariff Publishing Company et al.*, Civil Action No. 92–2854, "Competitive Impact Statement," March 1993, pp. 9-10].

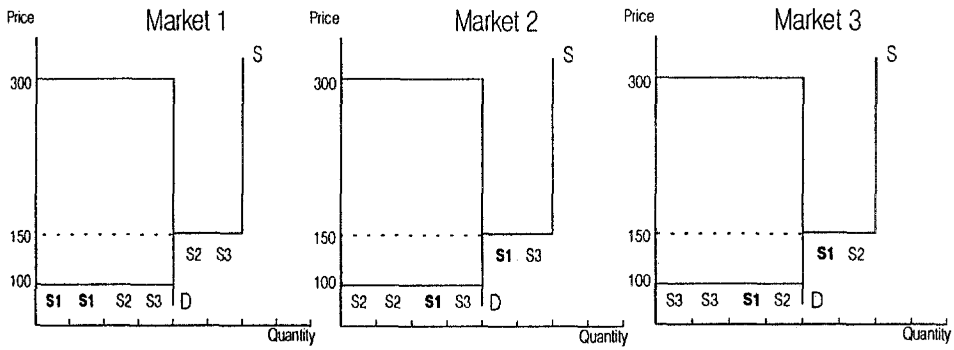

Fig. 1. Induced supply and demand arrays.

buyer purchased up to 4 units in each market at prices up to 300, as indicated by the demands in Figure 1. The buyer bought the lowest-price units available, and sellers were fully informed of the exact supply and demand conditions.

Aggregate demand was set at four units in each market. This has two implications: First, no seller has power in any market, since any unilateral deviation from the competitive price would result in zero sales for the defecting seller.[11] Second, although there is no natural collusive allocation in any single market, when the markets are pooled a rather obvious allocation arises: Each seller should offer all their low cost units for sale at the limit price of 300. Such an allocation would result in an equal division of the total available surplus.[12]

This specification of supply and demand is not intended to characterize any natural market or industry. It does, however, parallel an important feature of the airline industry; although each seller has a cost advantage in their home (hub flight) markets, the advantage is not so great that the low cost seller can raise price without fear of being largely, or even entirely usurped by competitors.

[11] But the competitive equilibrium is not a Nash equilibrium. In any market, if 6 units are offered for 150 each, any seller could unilaterally increase expected earnings by posting a price of 149. But if all sellers post 149, only 4 units are offered, and any seller could profitably increase price to 300. In fact, in this design there is no pure-strategy Nash equilibrium for the stage game (although, as noted subsequently, pure (trigger-) strategy equilibria exist in the multi-period game). The unique static Nash equilibrium involves mixed strategies. Mixing distributions for each seller are calculated by finding for each seller the pricing distribution that makes all other agents indifferent between earning "security" profits associated with pricing just below 150, and randomizing. Relevant distributions are $F(p) = [(p - 150)/(p - 100)]^{1/2}$ for the small sellers, and $G(p) = [(p - 150)(p - 100)/(p - 125)^2]^{1/2}$ for the large seller. Respective distributional medians are 167 and 154.

[12] We are grateful to an anonymous referee for pointing out that Bernheim and Whinston's symmetry irrelevance result implies that there are no more noncooperative Nash equilibria in our symmetric multi-market design than exist in any of the single markets. Our motivation for anticipating supracompetitive prices (either with, or without communications) more nearly follows the reasoning articulated by Scott (1993, ch. 2), who observes that even in a symmetric setting, multi-market contact remains relevant for oligopolistic pricing, since sellers can exploit extra learning opportunities available in the multimarket context to select more profitable equilibria.

The principle treatment variable is the opportunity for nonbinding price communications. In five "communications" sessions, sellers were given 2 minutes to publicly post and alter price/quantity offers in each market.[13] At the expiration of the 2-minute signalling phase, standing price/quantity postings became binding and the buyer completed purchases for that period.[14] In the remaining five "no-communications" sessions, sellers submitted a single, binding price/quantity offer in each market.

The markets were implemented using the Multiple Unit Double Auction (MUDA) software (Plott, 1991). Each market was presented to participants as a triplet of horizontal lines on their screen, where sellers S1, S2 and S3 posted prices, respectively. In the communications sessions, sellers could modify their postings as often as desired (which could be accomplished merely by pressing ALT-F4 to remove their standing price, and then entering another). Providing a separate row for each seller in each market allows sellers to continuously monitor all proposed price/quantity offers.

In the no-communications sessions, sellers wrote their price and quantity decisions on a slip of paper and handed it to an experiment monitor. Sellers were bound to their written decisions, and entered them into the computer only after all slips had been handed to the monitor. In this way, sellers made only binding, simultaneous price/quantity offers, as in the usual posted-offer institution.

In both treatments, the monitor made and publicly announced purchasing decisions in each market once binding price and quantity decisions were entered. Sellers recorded all 9 posted prices and their own sales, and calculated their earnings by hand on a record sheet.

In other respects procedures were standard. Instructions were read aloud to participants as they followed along in their own copies.[15] Following a practice period, each session consisted of a minimum of 20 trading periods. After period 20, a die was tossed prior to the start of each period, and the session was terminated with the first roll of a 5 or a 6. The 1/3 termination probability implied by this random stopping rule induces a discount factor of 2/3, which is sufficient to support prices up to the limit price of 300 as Nash equilibria for the repeated multi-market game.[16] The longest session lasted 26 periods.

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[13] The 2-minute, continuous communications period is adapted from Cason (1995). We increased the signalling period from 1 to 2 minutes to compensate for the extra complexity associated with allowing sellers to send messages in three different markets.

[14] Thus, we do not implement a partial quantity, or "last ticket date" option. Nevertheless, sellers could signal both price decreases and price increases in our environment.

[15] Instructions are available from the authors, on request.

[16] Consider a "grim" trigger strategy equilibrium, where all sellers play the joint-profit-maximizing outcome unless there is a defection, in which case all sellers permanently revert to the static Nash equilibrium (described in note 11) in all markets. In the joint profit-maximizing-outcome each seller earns 800 per period (400 from the sale of 2 units in their low cost market, plus 200 from one sale in each of the other markets). By shading on the limit price, any defector can sell an additional two high-cost units and increase profits by slightly less than 300, for a total just under 1100. Finally, in the competitive outcome, each seller randomizes with the expectation of earning security profits of

TABLE I. Matrix of treatments and some summary performance measures: periods 1–20.

(1)	(2) $P - P_c$[a]	(3) M[b]	(4) Efficiency[c]	(5) $\sigma_{earnings}$[d]
No Communication				
1-SC	46	20.6	92.7	3.87
2-VA	18	2.5	95.3	0.17
3-VA	13	−1.8	96.0	0.57
4x-SC	77	41.3	92.6	4.19
5x-VA	25	10.0	93.5	0.59
Avg.	36	14.5	94.0	1.88
Communications				
C1-SC	64	32.7	92.5	7.10
C2-SC	96	54.0	92.3	2.76
C-VA	30	8.1	93.2	1.08
C4x-SC		85.7	92.4	2.06
C5x-VA	57	21.1	92.8	2.79
Avg.	78	40.3	92.6	3.16

[a]P = average price; P_c = competitive equilibrium price (150).
[b]M = index of monopoly effectiveness.
[c]Efficiency = overall (buyer and seller) market trading efficiency.
[d]$\sigma_{earnings}$ = standard deviation of seller earnings.

Participants were undergraduate students recruited from economics courses at the University of Southern California and the University of Virginia. Participants were uniformly given a $6 appearance fee for making their appointment, plus their earnings in the course of the session.[17] Laboratory earnings were converted to U.S. dollars at a 5 to 1 rate. Earnings ranged from $14.50 to $39 for the sessions, which lasted for approximately two hours. Average earnings were $23.00.

A complete description of our experimental design is provided by the session identifiers listed in the left column of Table I. Each identifier consists of a number in sequence, followed by a University code (SC or VA). The session number is preceded by a "C" if nonbinding communications were allowed, and finally, an "x" designation follows the session number to indicate that participants had previously participated in a multi-market session.[18] Thus, for example, session

100 in their low cost market and 50 in each high cost market, for a total profit of 200 per period. Under these conditions, cooperation is profit-maximizing as long as $800/(1 - p) > 1100 + 200p/(1 - p)$, or as long as $p > 1/3$. Given $p = 2/3$, it easily follows that the threat of reverting to competitive pricing will support a multi-market equilibrium at any common price above 200.

[17] A series of minor technical problems slowed the administration of session C3-VA. To compensate participants for their extra time, they were paid an extra $5 bonus.

[18] Experienced participants were in a different cohort, and often used a different design in their initial trial. No one participated in more than two sessions.

C5x–VA printed at the bottom of Table I identifies the 5th session in the communication treatment. The session used experienced participants from the University of Virginia.

As is evident from Table I, the design is balanced in a number of dimensions. Five sessions were conducted under each communication treatment, and five sessions were conducted at each university. Two sessions in each communications condition (and at each university) used experienced participants.

IV. Results

1. Transaction Price Paths

Figure 2 presents all price offers of session C5x–VA. The three markets are stacked horizontally, and each price offer – including every canceled offer (or signal) – is listed sequentially in temporal order, with either a '■ ' (for sellers 1 and 2) or a '+' (for seller 3). Typically, the final 3 offers in each market each period are the binding, final price offers. Except in the case of tied prices, the buyer usually purchased units from the lowest two of the three binding offers. The three solid lines superimposed on these offer charts indicate mean *transactions* prices across periods for the three markets.

The session represented in Figure 2 is typical of the signalling sessions and illustrates several behavioral regularities of these markets. First, sellers signal prices actively, which generates a substantial amount of information each period. During the 2 minute signalling phase of each period, sellers entered an average of 15 price quotes across the 3 markets. (At the end of each period, 9 of these price quotes became binding offers, so an average of 6 quotes per period can be regarded as pure signals.) Second, note the volatility of prices across periods within the session. This volatility is characteristic of many sessions, including some in the no-communications treatment. Finally, note the correlation of transaction prices across the three markets. This correlation is high in all 10 sessions reported here, which allows us to pool prices across the three markets in the analysis below without losing much information.

Mean price paths for the five no-communications sessions and the five communications sessions are shown in the upper and lower panels, of Figure 3. Despite the variability of prices within treatments, some patterns are evident. Most prominently, prices tend to be higher in the communications sessions. Overall, the difference in prices is large. For example, as shown in column 2 of Table I, for the 20 periods common to all sessions, price deviations from the competitive equilibrium are more than twice as large in the communications treatment as in the no-communications treatment (78 vs. 36 cents, respectively). The price difference is statistically significant. The null hypothesis of no difference in mean prices may be rejected at a 90%

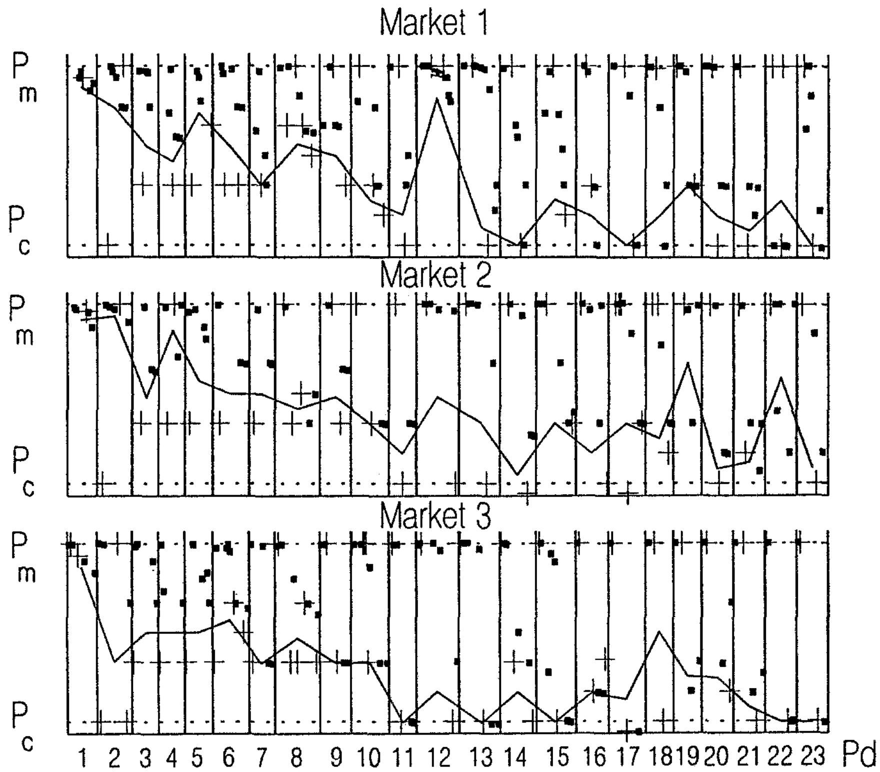

Fig. 2. Sequence of price quotes for session C5x-VA (Key: '■' quotes by sellers 1 and 2; '+' quotes by seller 3; Solid lines = mean transactions price paths.)

confidence level (direction not predicted) using the nonparametric Mann-Whitney test.[19]

Moreover, the price paths differ across treatments. In the no-communications sessions, prices are drawn toward the competitive prediction in the first half of each session, but then tend to rise again in the latter half. Such behavior is typical of posted-offer markets when the competitive equilibrium is not a Nash equilibrium (e.g,. Davis and Holt, 1994; Brown-Kruse, Rassenti, Reynolds and Smith, 1994). This U-shaped pattern of average prices is absent from the communications sessions shown in the right panel of the figure.

Figure 4 clearly illustrates the difference in price paths across treatments. This figure shows the pooled mean price paths for the 20 periods common to all sessions in the two communication treatments. To capture some of the diversity in performance across sessions, 5-period averages for each no-communication and commu-

[19] The Mann-Whitney test statistic value is 4, which equals the 90% critical value for the Mann-Whitney test with $n_1 = n_2 = 5$ observations per cell. This null hypothesis is rejected at the same or a higher level of confidence in 12 of the 20 periods individually. For a description of the test, see Conover (1980), p. 280.

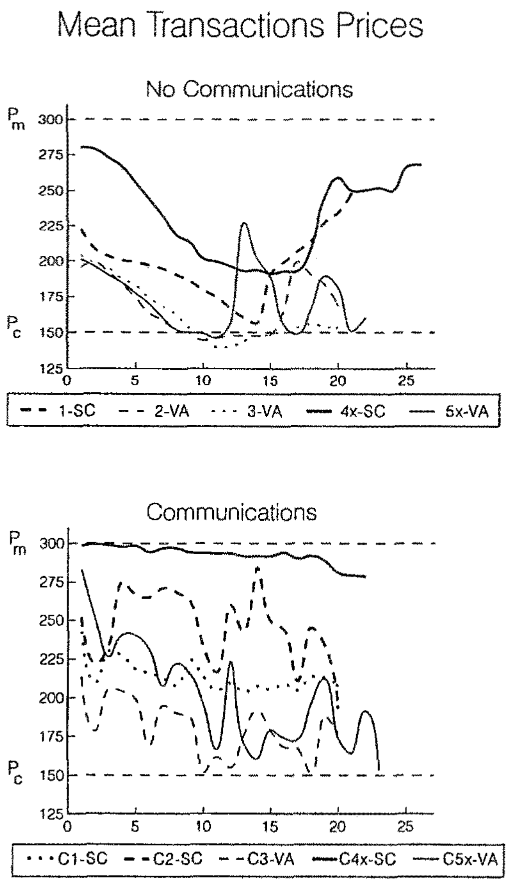

Fig. 3. Mean price paths.

nication session are listed vertically as dots and crosses, respectively. As suggested by the separation of dots and crosses in the middle two 5-period increments, the effects of communications occur largely in the middle of the session. For example, four of the five lowest mean prices were observed in the no-communications treatment in periods 6–10. Similarly, five of the seven lowest prices were in the no-communications treatment in periods 11–15. Using a Mann-Whitney test, the null hypothesis of no difference in mean prices for either of these 5-period sequences may be rejected at a 90% confidence level (direction not predicted).[20] Although mean prices are also lower for the no-communications sessions in the initial and terminal 5-period sequences, the differences are smaller and are no longer sta-

[20] Mann-Whitney test statistic values for periods 6–10 and periods 11–15 are both 4, which equals the 90% critical value for the Mann-Whitney test with $n_1 = n_2 = 5$ observations per cell.

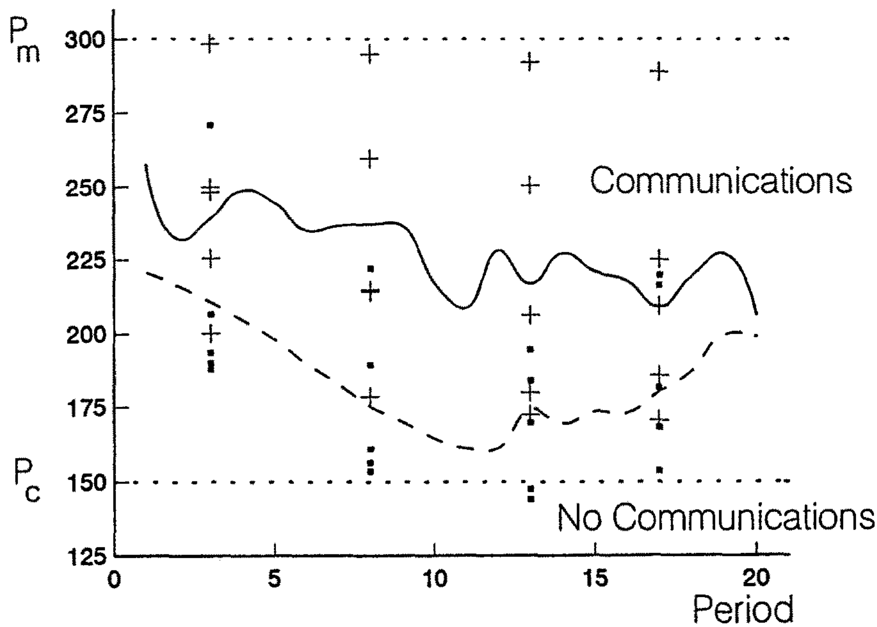

Fig. 4. Aggregate mean price performance (key: '+' 5-period mean price in communications sessions; '■', 5-period mean price on no-communications sessions).

tistically significant.[21] Combined, the above observations generates our first, and principle conclusion:

Conclusion 1: In this multi-market environment, opportunities for nonbinding communication affect the price path. In contrast to no-communications sessions, sellers are less likely to engage in a price war before organizing price increases.

Prior to examining evidence pertaining to tacit conspiracy, two additional observations regarding the effects of communications that may be drawn from Figure 4 merit brief comment. First, as suggested by the initially higher and more slowly decaying prices in the communications treatment, there appears to be an immediate benefit to sellers of increased communications possibilities. Prior even to the possibility that any conspiratorial arrangement has evolved sellers post higher prices, perhaps out of a simple optimism that cooperative behavior is more likely. However, the slow reduction in average prices in the communications treatment indicates that sellers are not learning to collude more effectively by exchanging price announcements. Second, the decay in the difference between the two treatments is not due to extra-competitive end-period effects (as we hoped to avoid with our probabilistic termination rule). In both treatments, mean prices substantially exceed P_c in the terminal periods. Moreover, the price path levels off in

[21] Mann-Whitney test statistic values are U = 5 and U = 7 for periods 1–5 and periods 16–20, respectively.

latter periods of the communications treatment, and even trends upward in the no-communications treatment. Thus, whatever the consequences of communications, they are dominated by neither a communications "learning" effect, nor an "end-play" effect.

2. Signalling Activity and Factors that Affect the Success of Tacit Conspiracy

Despite conclusion 1, the way that the price communications affects pricing is unclear. We observed no instances in which sellers organized a stable, fully efficient conspiracy, and anecdotal evidence suggests that sellers find it difficult to develop a language of conspiracy from communications restricted to price offers. For example, prior to session C5x−VA, one of the sellers privately asked the experimenter if he could talk to the others before the session. He indicated that from his experience in a previous session, he appreciated that there was a lot of money to be made for all with a little cooperation. We instructed him to not talk to the others. The price offers for this seller (S3) are highlighted with crosses ('+') in Figure 2, and he evidently found the ensuing session a very frustrating experience. After failing to get the other sellers to maintain uniformly high prices in periods 1 and 2, or high prices in a single market in periods 4–6, seller S3 developed a consistent strategy of opening with the limit price in each market, and then punishing with a lower price when the other sellers began to price shade. In period 9, for example, S3 opened with an efficient allocation at the limit price in all markets. The seller then reverted to a "punishment" price of 200 in all markets when the other sellers began to undercut him. By period 11, the punishment response price was decreased to 150, and, with a few exceptions, remained there for the rest of the session. As indicated by the transaction price paths, these signalling efforts were fruitless: The other sellers never responded to the signals, and after considerable fluctuation, prices decayed toward the competitive level.

In contrast, the more successful conspiracies tended to be a consequence of one or more sellers posting high prices, and tolerating the consistent defections of the others. For example, the very high prices in session C4x−SC (shown as the thick bolded line in the bottom panel of Figure 3) were maintained by sellers S1 and S2 cooperating by posting near limit prices in all markets, and tolerating consistent defections by seller S3. Figure 5 contains the sequence of offers for periods 11–22 of this session. The defecting seller S3's price offers are highlighted on this figure with the '+'. Note that S3's offer is often the lowest among the final 3 (i.e., typically binding) offers each period. This pattern resulted in rather divergent earnings among the sellers. For example, over the last 10 periods of the session, S1 and S2 each received 29% of the total earnings, while S3 collected 42%. A nearly identical earnings profile was generated in the last half of the session with the second highest prices, session C2-SC, indicated by the bolded line with long dashes at the bottom of Figure 3. In session C1-SC, illustrated as the bolded line

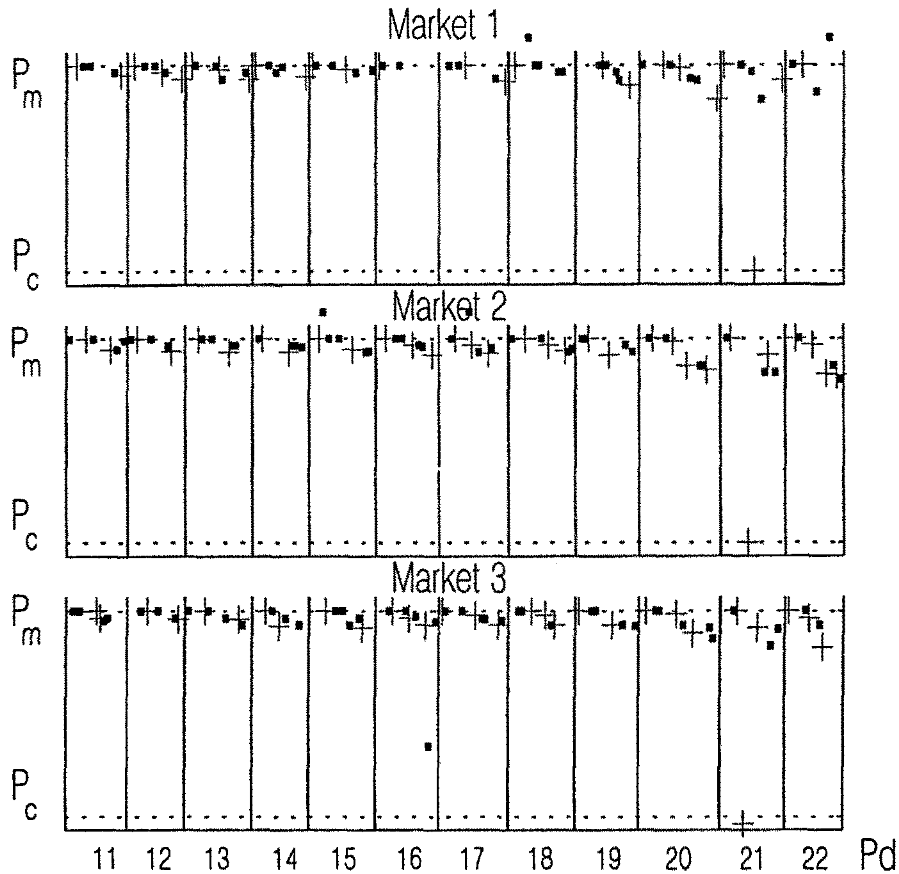

Fig. 5. Sequence of price quotes for the last half of session C4x-SC. (Key '■' quotes by sellers 1 and 2: '+' quotes by seller 3.)

with short dashes in Figure 3, the situation was even more extreme: The higher prices were a consequence of only one seller (S3) posting the higher prices, so in the last half of this session sellers S1 and S2 each collected a 40.33% earnings share, while S3 earned a 19.33% share.

No obvious summary measure captures the relationship between communications activity and prices. For example, a high volume of messages may indicate open and very effective agreements, an effort to restore previous high prices, or nothing more than boredom among the sellers waiting to post prices.[22] Something may be said, however, about the behavioral factors that affect the success of tacit conspiracies by reviewing the summary measures listed in Table I. First, the monopoly effectiveness "M" values listed in column (3) measure the extent that

[22] In fact, after controlling for the period number, we found very little evidence of any correlation between the volume of communications and prices.

sellers captured the maximum possible gains from conspiracy.[23] It is worth noting that the sellers are far from joint-profit maximizers: Sellers realized more than half of the possible supra-competitive profits in only 2 of the 10 sessions.

Compare now the M values with the surplus extraction rate, measured as the Efficiency index in column (4).[24] Efficiency values are uniformly high (in excess of 92%), as would be expected given fully revealing buyers and complete demand information. The range of efficiency values is more interesting, however, when viewed in light of the maximum losses possible for rational traders when trading volume is the maximum of 12 units. Efficiency losses occur only when one or both of the high cost sellers in each market sell both of their high-cost units (generating single-market losses of 6.25% and 12.5%, respectively). Column (4) indicates that sellers managed to constrain losses to less than one low-cost unit per market per period (93.75%) only twice, both of which occurred in the no-communications treatment. Moreover, there is a strong inverse relationship between Efficiency and Monopoly Effectiveness: The Spearman rank-order correlation coefficient between E and M is −0.952, and the null hypothesis of no correlation may be rejected at a 99% confidence level (t = −8.75; 8 d.f.). Thus, with or without communications, sellers do not organize efficient conspiracies.

Rather, as suggested by the above characterization of the more successful conspiracies, high prices are typically the result of some subset of the sellers supporting defections by remaining sellers. This relationship is more systematically documented by comparing M values with the standard deviation of earnings across sellers, σ_{earnings}, listed in column (5) of Table I. There is a strong negative correlation between M and σ_{earnings}, with the Spearman rank-order correlation coefficient of −0.84 allowing rejection of the null hypothesis of no correlation at a 99% confidence level (t = −4.42, 8 d.f.). Thus, rather than rationing capacity to generate an efficient conspiracy – in this context, one that also generates equal earnings per seller – high prices are generated by one or more sellers supporting the others. Communications appear to facilitate the incidence of sellers willing to support such behavior. Combined, these observations form of our second conclusion.

Conclusion 2: Although mean prices are higher on average in the communications sessions, sellers do not develop an obvious "language of conspiracy." Rather, conspiracies are more successful when a subset of the sellers support the remaining competitors. Communications appear to affect the rate at which sellers elect to engage in such supportive behavior.

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[23] M values are calculated as the percentage of possible monopoly gains extracted, or $M = 100(\pi_o - \pi_c)/(\pi_m - \pi_c)$, where π_o denotes observed profits, π_c competitive profits, and π_m monopoly profits. M=100 when sellers extract the uniform-price joint-profit-maximizing outcome, and M=0 in the efficient competitive outcome. Notably, M is not bounded by the (0,100) interval, due the possibilities of price discrimination and lower-than-competitive earnings. The values in Table I are based on results of the 20 periods common to each session.

[24] $E = 100(PS_o + CS_o)/(PS_c + CS_c)$, where PS_o and CS_o are observed producer and consumer surplus, and $PS_c + CS_c$ is the maximum possible surplus. Index values range between 0 and 100.

3. Other Environmental Factors Affecting Tacit Conspiracy

Other factors also prominently affect prices. This is evident from further inspection of the mean price paths for individual sessions, in Figure 3. In the figure, experienced sessions are indicated by unbroken lines, while inexperienced sessions are represented by both short-dashed and long-dashed lines. Lines indicating sessions conducted at the University of Southern California are bolded. Casual examination of these charts suggests that both experience and the location of the session importantly affect the likelihood of collusion. A more precise indication of the effects of other variables can be seen by regressing M values against the experimental treatments: Location, experience level and communications. This analysis of variance renders Equation (1):

$$\begin{array}{lllll} M = & -7.6+ & 35SC+ & 20X+ & 18.8C \\ & (1.04) & (4.36^{**}) & (2.47^{*}) & (2.29^{*}) \end{array} \quad (1)$$

$$R^2 = 0.78 \quad F_{3,6} = 11.68^{**} \quad d.f. = 6$$

* Significant at 90% confidence level (direction not predicted)
**Significant at a 99% confidence level (direction not predicted).

Where SC = 1 if the session was conducted at the University of Southern California; X = 1 if experienced participants were used, and C = 1 indicates that nonbinding communications were allowed.

As indicated by the regression, although the opportunity for price signalling generates a large and statistically significant effect, it is no more important than the effect of experience with the design, and may be considerably less important than where the sessions were conducted.[25] Undergraduate students at the Universities of Southern California and Virginia do not differ in any obvious demographic or sociological characteristics, so the performance difference is likely due to the difference in experience profiles: All but one of the USC subjects had participated previously in a double-auction session with the MUDA software. UVA students had experience with a computerized posted-offer market, but using different software. Thus, we may regard the USC students as advantaged, due to "mechanism-experience." Results of the regression analysis generates our third, and final conclusion.

Conclusion 3: Nonbinding communications are neither the only, nor the most important factor affecting price performance. Both experience in a design, and previous experience with the pricing mechanism each have effects that rival the consequences of allowing price communications.

[25] The hypothesis that the SC and C coefficients are equal cannot be rejected ($F_{1,6}$ = 1.67). The importance of experience is suggestive of Scott's (1993) discussion that multimarket contact facilitates the selection of more profitable equilibria through learning (see note 12). Nevertheless, this observation remains speculative, since direct evaluation of the learning-enhancing capacity of multi-market contact would require a set of parallel sessions conducted in a single-market design, a project beyond the scope of this paper.

Nevertheless, Equation (1) indicates that communication opportunities increase seller profits even after controlling for these experience factors.

V. Closing Remarks

This study represents a first effort to combine the effects of multi-market competition and communications. We find that communications clearly affect the price path in a multi-market environment. In this design, however, sellers do not appear to use the communications to develop the expected punish /reward language economists typically employ in theoretical models of tacit collusion.

Of course, we must be very cautious in drawing inferences from the laboratory about the extent to which other nonbinding price communications mechanisms, such as that investigated in the airline industry by the Department of Justice, affect transactions prices. Our market environments are both more simple and of much shorter duration than their naturally occurring analogues. Some findings, however, are suggestive. First, it is exceedingly difficult to develop an effective "language of communication" when communications are limited to price offers, even in the presence of a multi-market structure that facilitates the distinction of punishments from defections, and even when the underlying market structure is not particularly competitive. Second, with or without communications, most tacit-conspiracies arise when one or more of the sellers support defections of others. Casual observation of conspiracies in natural contexts, such as the role of Saudi Arabia in the OPEC cartel provides anecdotal support of this latter observation.

A number of important dimensions remain to be explored. Sellers, for example, may be more inclined to coordinate when the costs of a coordination failure are more pronounced. One promising environment might be a design similar to the one investigated here, but where sellers have high fixed costs and low marginal costs. Such a design would emulate the "avoidable cost" (e.g., don't fly, don't pay) structure of airline competition. Also, it may be useful to enrichen the communications structure to allow sellers to communicate seller codes and first and last effective dates for prices, along with price-postings. Such behavior was part of the communications scheme in the ATP suit, and may foster development of a more obvious "language of conspiracy."

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