Buyer Concentration as a Source of Countervailing Power: Evidence from Experimental Posted-Offer Markets

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Abstract: We experimentally examine the impact of buyer concentration on the pricing of a monopolist. In our experimental markets, a monopolist faces either two or four buyers. Markets with two buyers achieve significantly lower prices, sometimes below competitive levels, than those with four buyers. We design an additional pair of treatments to pinpoint the source of this difference. We attribute the lower prices in the two-buyer treatment to the monopolist pricing more cautiously when there are fewer buyers in order to avoid costly losses in sales. Buyer concentration may thus be an effective source of countervailing power.

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1 Introduction

> "In the typical modern market of a few sellers, the active restraint is provided not by competitors but from the other side of the market by strong buyers ... At the end of virtually every channel by which consumers' goods reach the public there is, in practice, a layer of powerful buyers." (Galbraith, 1952, pp. 112, 126)

> "I would expect bilateral oligopoly to be relatively monopolistic in operation ... it simply is romantic to believe that a competitive solution will emerge, not merely in a few peculiar cases, but in the general run of industries where two small groups of firms deal with one another suddenly all the long-run advantages of monopolistic behavior have been lost sight of in a welter of irrational competitive moves." (Stigler, 1954, p. 9)

Buyers are typically treated as passive price-takers in economic theory with sellers as the only strategic players. Yet in non-retail trade, there is no theoretical or apparent reason why buyers should be any less influential in establishing the price than sellers. Since Bertrand's (1883) provocative finding that two firms competing in prices are sufficient to bring about the competitive outcome, the question of the competitiveness of a market as a function of seller concentration has been a hotly debated one.[1] In sharp contrast, the analogous topic concerning the impact of buyer concentration on market outcomes remains underexplored.

Galbraith (1952) introduced the notion that a small number of buyers can act as a countervailing force against the market power of a small number of sellers. His idea, however, was initially dismissed as far-fetched (see e.g. Stigler, 1954, and the above quotation, and Hunter, 1958). More recently, however, numerous cross-sectional empirical studies demonstrate that the more concentrated the buyers' side of the market, the lower are sellers' price-cost margins (see, e.g., Scherer and Ross (1990, pp. 533-535) for an overview of this evidence).

In this paper we examine experimentally the ability of a small number of buyers to influence monopolist pricing and the means by which buyers are able to do so. We do this by comparing the pricing of a monopolist in a full-information, 30-round experimental market with two buyers to pricing in an identical market with four buyers. In our posted-offer markets, the monopolist makes a take-it-or-leave-it offer to buyers who then decide whether to accept or reject the offer. Strategic buyer behavior is therefore limited to rejecting profitable purchases, i.e. rejecting purchases at a price below the buyer's valuation, referred to as demand withholding. In our experiments, buyers

[1] See, for instance, Stiglitz (1987), Dufwenberg and Gneezy (2000), Isaac and Reynolds (2002), and Huck et al. (2004).

are unable to collude, to make a counter-offer or negotiate a better price.

Our results show that markets with two buyers attain significantly lower prices than those with four buyers, despite the inability of buyers to coordinate with one other and other controls built into the experimental design. In order to understand the behavioral mechanism through which concentrated buyers affect monopoly pricing, we designed an additional pair of treatments in which the monopolists, but not the buyers, were unaware of the number of buyers in the market. Results from these "uninformed" treatments indicate that it is more likely that monopolists price cautiously when facing more concentrated buyers than it is that concentrated buyers act to bring down prices through increased demand withholding. Dynamic panel regressions support this conclusion.

These experiments highlight the countervailing role that buyer concentration may play in real-world markets: even when changes in the number of buyers (either through mergers, entry or exit) may be observed in real-world industries, concurrent unobservable changes (e.g., in demand conditions) are likely to follow, rendering attempts to disentangle the effect of buyer concentration difficult at best. Laboratory experiments have the ability to control for such unobservables and thus isolate the impact of buyer concentration.

Our results begin to fill a gap for evidence-based antitrust policy, which recognizes the potential role buyers may play in preventing collusion, but which lacks clear guidelines in practice. The 1982 revisions to the Horizontal Merger Guidelines cite the "ability of sophisticated buyers to devise long-term contracts to break collusive agreements" as a measure to evaluate the competitiveness of an industry. However, the absence of clear empirically established criteria or theoretical benchmarks for buyers' influence may explain what may be interpreted as the courts' reluctance to approve mergers despite a seemingly concentrated buyer side of the market. For instance, in United States v. Country Lake Foods, Inc. (1990), the court refused to enjoin a merger where three large customers accounted for 90% of all purchases in the relevant product market. More recently, America's first and second largest pharmaceutical companies concurrently proposed to merge with the industry's fourth and third largest firms, respectively. The justification put forth for these multi-billion dollar mergers was the claim that 80% of the estimated $306.9 million in fixed-cost savings due to the elimination of redundancies would be passed onto large pharmaceutical buyers, mainly hospitals,

purchasing blocs that represent groups of hospitals and retail chains like Wal-Mart, in the form of lower prices. Again, perhaps in the absence of well-established guidelines for the countervailing ability of large buyers, the courts (FTC v. Cardinal Health and FTC v. McKesson Corp.) blocked both mergers. Our results suggest that pricing behavior may indeed be influenced by the number of buyers in a market.

Section 2 surveys the role of buyers in the experimental literature. We detail the experimental design and procedures for the two-buyer and four-buyer "informed" treatments in section 3. Section 4 presents the results of these treatments as well as the results for two additional "uninformed" two-buyer and four-buyer treatments. In section 5, we discuss the importance of the experimental parameters and information for demand withholding and the exercise of monopoly power, and explore an application of our results to increasing industrial concentration. Section 6 concludes.

2 Buyer Behavior in Previous Posted-Offer Experiments

In a posted-offer market experiment, sellers offer to sell a specific quantity of a good at a price, and then buyers accept or reject the offers. Supply and demand curves are induced in the game such that for any finitely repeated game, the unique subgame-perfect equilibrium is for buyers to make all profitable purchases in each period. Most posted-offer market experiments implement this solution by replacing human with simulated buyers. These computerized buyers automatically purchase from the lowest-price seller and continue to do so as long as the price is less than (or equal to) the buyer's valuation.

Computerized buyers have been standard in this literature because researchers have focused on seller behavior; by eliminating variation among the buyers, seller behavior can be studied in a highly controlled setting. Nonetheless exceptions to the replacement of human buyers with a myopic profit-maximizing computer algorithm do exist.[2] Smith (1981), for example, conducts a single experimental session with a posted-offer monopolist facing five human buyers. In his 11-round experiment, not a single instance of withholding is observed and prices converge in period 5

[2] See Ruffle (forthcoming) for a detailed survey of the experimental and theoretical literatures on buyer power.

to the monopoly price.

Other experiments comparing human and simulated buyers reveal less extreme buyer and monopolist behavior. Coursey, Isaac and Smith (1984) and Brown-Kruse (1991) test the contestable markets hypothesis with a decreasing-cost monopolist facing either computer-simulated or five human buyers. The decreasing-marginal-cost structure implies that demand withholding hits the monopolist's most profitable units first. Both studies find that prices approach or even converge to competitive levels. Moreover, while prices are lower in sessions with instances of demand withholding, the mere presence of human buyers is sufficient to bring about lower prices compared to sessions with simulated ones.

Ruffle (2000) tests the impact of a number of variables on demand withholding and the pricing of duopolist sellers. Fewer buyers and experimental designs with more unequal surplus divisions at the market-clearing price in favor of the sellers are shown to increase withholding and lower duopolists' posted prices. One possible explanation for the effectiveness of two buyers in Ruffle (2000) is that if one of the two buyers withholds his units of demand, then the two sellers must compete in price for the business of the remaining buyer. This led to the observed downward spiral in prices. The four-buyer treatments, by contrast, require three of the four buyers to withhold their entire demand schedules for this fierce price competition between sellers to ensue.

Normann, Ruffle and Snyder (2005) relax the assumption of buyers of equal size to explore the impact of buyer size on posted bids against a monopolist in markets with either decreasing, constant or increasing marginal costs. In accordance with the theory, large-buyer discounts emerge only in the case of increasing marginal costs.

Davis and Wilson (2006) depart from earlier private-information posted-offer experiments by making the supply and demand curves common knowledge. They examine the impact of mergers (quadropoly to duopoly) with fixed-cost, variable-cost or no-cost synergies on pricing in which firms face either human or simulated buyers. Human buyers attain significantly lower prices than simulated ones, both pre- and post-merger. In addition, human buyers are able to extract a portion of both fixed- and variable-cost synergies from the sellers.

Our paper differs from the existing literature in several respects. While Ruffle (2000) and Davis

and Wilson (2006) study markets with multiple sellers, we control for price competition between sellers by studying monopolies. Also unlike Davis and Wilson (2006), we design treatments to understand the source of the lower prices observed when buyers are concentrated. By endowing each buyer regardless of treatment with the identical individual demand curve, we control for differing opportunity costs of withholding among buyers that may account for the results in Ruffle (2000). Finally, we focus on the number of buyers, rather than their size as in Normann, Ruffle, and Snyder (2005).

3 Experimental Design and Procedures

3.1 Experimental Design

Subjects were randomly assigned the role of buyer or seller in markets with a monopolist and either two or four buyers. Buyers were given a schedule of valuations for units of a good, and sellers were given a schedule of costs. To induce subjects to trade, they were told that buyers earn the difference between their valuations and the price they pay on each unit they purchase, while the seller earns the difference between the price and his cost on each unit sold. The costs of unsold units are not subtracted from the monopolist's profits.

Figures 1a and 1b display the monopolist's marginal cost curve and the buyers' aggregate demand curve for the two-buyer and four-buyer treatments, respectively. The figure reveals that every buyer possesses four units of demand regardless of experimental treatment, the first unit of which is valued at 35 units of currency above the competitive price (+0.35), the second and third units have values of +0.20 each, and the fourth unit has a value of +0.05.

These parameters remained static throughout the 30-round experiment, and were made common knowledge by providing each subject with a table of costs and values of all subjects, and by reading aloud the contents of the table. The market structure in these two treatments was also common knowledge so that the monopolist (and the buyers) knew precisely how many (other) buyers were in the market. The results of these "informed" two-buyer and four-buyer treatments led us to design two additional treatments in which the monopolist was uninformed of the number of buyers in the

market.[3]

We held constant across treatments a number of variables believed to be important to demand withholding and seller pricing. For instance, notice that both treatments share the same ten-unit, competitive price range. The midpoint of the competitive range has been normalized to zero, with all other prices, costs and valuations henceforth expressed as deviations from this competitive price.[4] Moreover, both treatments share the identical monopoly price of 20 units of currency above the competitive price (+0.20).

[insert Figures 1a and 1b here]

These parameters are based on experiments in Ruffle (2000). In that paper, two sellers faced either two or four buyers. The demand and cost parameters in two of the treatments (2b3sF and 4b6sF) correspond exactly to those in our two-buyer treatment in Figure 1a. The difference between these two treatments in Ruffle (2000) is that the duopolists faced two buyers in one treatment (2b3sF) and four buyers in the other (4b6sF). Buyers in the 2b3sF withheld seven times as many units of demand as those in 4b6sF, leading to significantly lower prices. The most probable explanation for the relatively intense withholding in 2b3sF is that each buyer possessed twice as many units of demand compared to buyers in 4b6sF, thereby lowering buyers' marginal cost of withholding. To control for this explanation, we have endowed all buyers in these experiments with identical individual demand curves, regardless of identity or treatment.

Another variable found to be important for the exercise of buyer power and duopolists' pricing in Ruffle (2000) is the theoretical surplus division between individual buyers and sellers at a benchmark price. To hold this constant across our two treatments in which all buyers in both treatments are endowed with identical individual demand curves requires a shift in portions of the monopolist's cost curve. Given the abundance of theoretical, empirical and experimental evidence of the relevance of fairness and inequality aversion in determining price outcomes and the absence of such evidence

[3] We discuss this second set of "uninformed" treatments in Section 4.2.

[4] The actual competitive price was 1.90 for half of the experiments and 3.90 for the other half. This between-experiment, two-unit shift is standard practice in market experiments to avoid the critique that the observed results are dependent on the particular parameters chosen. We find no significant difference in monopolists' prices between the two sets of parameters.

about the height of portions of the seller's cost curve, we elected to control for the former across markets, necessitating variation in the latter. The results from our two-buyer and four-buyer uninformed treatments provide evidence of the benignity of the change in interior portions of the monopolist's cost curve.

The cost curve in the four-buyer treatment (Figure 1b) has been chosen such that the monopoly price (+0.20) and competitive price (0.00) are the same in each of the treatments. Moreover, at the competitive price, the monopolist seller earns exactly six times as much as each buyer, independent of identity or treatment: each buyer earns 0.80, compared to 4.80 for the monopolist. Notice that the competitive, rather than the monopoly, price serves as our benchmark for fixing the surplus-division ratio. Duopolists' prices in Ruffle (2000) were found to converge to the competitive equilibrium or well below it. Despite a monopolist seller in our experiments, we (correctly) anticipated prices again to be around the competitive range. To see why, note that at the monopoly price, the seller earns 36.66 times as much as each buyer in the two-buyer treatment and 42.66 times as much in the four-buyer treatment. With full information about demand and cost parameters, even mild inequality aversion would push prices below the monopoly level. Thus, we do not view our experiments as a good test of monopoly power, but rather a well-calibrated test of the impact of buyer concentration on the pricing of a monopolist.

Our choice to employ a monopolist eliminates possible seller concerns and uncertainty about the simultaneous price choice of additional sellers, thereby allowing us to concentrate on the impact of the buyers' decisions on monopolist pricing without the complication of competition between multiple sellers.

Finally, four units of demand combined with the monopolist's cost curve imply that each buyer, again independent of treatment or identity, possesses market power. We adapt to the case of buyers the definition of seller market power applied by the 1984 Department of Justice horizontal merger guidelines. We define unilateral buyer market power as the ability of an individual buyer to deviate profitably from passive price taking.[5] Assuming that the seller and all other buyers behave competitively, an individual buyer in our experiments may profit by unilaterally deviating: by

[5] In Cournot quantity-choice experiments, Holt (1989) first implemented experimentally the notion of seller unilateral market power.

withholding two of his four units of demand, the resulting demand curve intersects the monopolist's cost curve at the second-to-last step. At the resultant lower price, the withholding buyer earns more from his two remaining purchases than he does by making all four profitable purchases at the original competitive equilibrium price.[6]

3.2 Experimental Procedures

All experimental sessions were computerized using software programmed in Visual Basic. Multiple experiments (of the same treatment) were conducted simultaneously (for instance, five four-buyer experiments at a time or eight two-buyer experiments at a time) to preserve subject anonymity.[7]

Each round in the posted-offer market consisted of the following sequence of events. The monopolist selected a price and chose a quantity to make available for sale at that price. The monopolist's price (but not quantity) was displayed to all buyers. The buyers were randomly ordered, and each buyer in turn proceeded to purchase the number of units that he desired. Buyers' purchasing and withholding decisions were made privately so that buyers were unable to observe the number of purchases (and units withheld) of other buyers. In addition, buyers did not learn the number of units sold by the monopolist. These institutional details rendered it impossible for buyers to coordinate their responses to the monopolist, to provide a particularly tough test of the ability of concentrated buyers to influence prices. The period ended when the last buyer had an opportunity to shop.[8]

This sequence of events was repeated for 30 rounds. At the end of the experiment, subjects were paid a 15 NIS (New Israeli Shekel) showup payment in addition to their experimental earnings. Average seller earnings (including the showup payment) were 121 NIS compared to 67 NIS for the buyers.[9] Sessions lasted between one hour and one hour and thirty minutes.

[6] The impact of demand withholding on this increasing-cost monopolist is still quite modest compared to a monopolist with decreasing costs against whom withholding would first hit his most profitable, lowest-cost units.

[7] The instructions to participants are available from the authors upon request.

[8] Note the structural similarity between the posted-offer monopoly game and the ultimatum game. The seller's posted price serves as a proposal to divide the available surplus with the buyers. Each buyer may then accept or reject the proposed surplus division. Despite their apparent similarities, results from dozens of experiments demonstrate that they are behaviorally distinct. Hoffman, McCabe, Shachat and Smith (1994) provide the most direct comparison of the two games by framing an ultimatum game as a posted-offer market. Their results show that the market frame produces significantly lower offers without affecting rejection rates.

[9] At the time these experiments were conducted 4 NIS was equivalent to approximately $1 U.S.

All sessions were conducted at Ben-Gurion University. Seven two-buyer informed experiments were conducted along with eight four-buyer informed experiments. (Recall that the "informed" experiments indicate that the monopolist knew the precise number of buyers in the market.) All subjects were economics or business majors and had taken at least an introductory course in microeconomics. Participation was restricted to one experiment per subject.

4 Results

4.1 Full-Information (Informed) Treatments

We begin by addressing the following two questions: 1) Are a small number of buyers able to bring prices down below the monopoly level? 2) Are two buyers able to achieve lower prices than four buyers? The summary statistics presented in Table 1 and the price graphs in Figure 2 answer both questions in the affirmative.

[insert Table 1 here]

Result 1 *Buyers in both treatments achieve prices significantly below the monopoly price. Moreover, prices in the two-buyer treatment are substantially lower than prices in the four-buyer treatment.*

The first noteworthy observation from these experiments is that buyers in these markets are able to obtain prices well below the monopoly price. As shown in Table 1, the median posted price taken over all periods in all experiments in the two-buyer treatment is -0.07, two units below the lower bound of the competitive tunnel. This same statistic for the four-buyer treatment is $+0.12$, midway between the competitive and monopoly prices.[10] These statistics hide the price dispersion across the different sessions. Column (1) of Table 1 organizes the experiments within each treatment in descending order by median session price (column (2)). What stands out are the three four-buyer experiments in which the price is just below the monopoly price (4B13, 4B14 and

[10] We report the median experiment and treatment prices throughout the paper. The mean prices are very similar if we exclude the first two periods in which in a few of the experiments prices are exceptionally high, above the buyers' valuations.

4B9), the three two-buyer experiments in which the price is substantially below the competitive range (2B6, 2B3 and 2B7), and the remainder of experiments (a mixture of two-buyer and four-buyer experiments) in which the price falls within the competitive range. Treating the median session price as one observation, we can reject the null hypothesis that the two price distributions come from the same underlying population distribution at the 98% confidence level (Wilcoxon-Mann-Whitney nonparametric test exact p-value=.020).

In the three four-buyer sessions (4B13, 4B14 and 4B9) in which the monopolist's median price is just a unit or three below the monopoly price, a comparison of columns (6) and (7) in Table 1 indicates that the monopolist earns between 13 and 49 times as much as the typical buyer in his session! These extreme earnings inequalities in conjunction with withholding levels that are relatively low (4B14 and 4B9) or slightly above average (4B13) make clear the strength of the posting side of the market and the apparent disregard for fairness considerations on both sides of the market in these full-information experiments.[11]

[insert Figure 2 here]

Another aspect of the difference in pricing between these two treatments can be seen in the price gap between them in the early and intermediate periods, as seen in Figure 2. Comparing the price distributions of the two treatments on a period-by-period basis (with a total of only 15 independent observations per period), the results of Wilcoxon-Mann-Whitney nonparametric tests indicate that we can reject the equality of the two price distributions at the 95% confidence level in periods 4, 7, 9, 12, 13, 14 and 16, and at the 90% confidence level in periods 2, 3, 8, 11, 15, 17, 18, 19, 20, 21 and 29. These results and Figure 2 also point to an end-game effect in these experiments: prices in both treatments converge to the competitive price range. Of the last nine periods, only period 29 yields a marginally significant difference between the price distributions of

[11] Plott and Smith (1984) discuss the relative weakness of the non-posting side of the market in posted-offer and posted-bid experiments. The stylized finding from posted-offer experiments is that prices settle at monopoly levels or converge slowly from above to the competitive equilibrium, even with advance seller production by which sellers incur the cost of production upfront (Mestelman and Williams, 1988) or with extreme earnings inequalities between sellers and buyers. Related to this latter case, Cason and Williams (1990) show that prices converge to the competitive equilibrium from above, despite a design in which the sellers earn all of the surplus at the competitive price. The fact that buyers accept such surplus inequalities in posted-offer experiments stands in stark contrast to many two-player bargaining game experiments, such as ultimatum and alternating offer games, in which 50:50 is the modal split.

the two treatments.

The regressions in Table 2 confirm the significant price discount in the two-buyer treatment and the end-game effect. The coefficient of 0.16 on the four-buyer treatment dummy in regression (1) reveals a 16-unit price premium on average compared to the two-buyer treatment. Dummies for each treatment interacted with a dummy for the last five periods indicate a significant end-game effect in the four-buyer treatment only as prices continue to converge to the competitive range from above. Interestingly, the impact of the previous period's sales lost to withholding on current-period price is not quite marginally significant (p=0.107).

[insert Table 2 here]

The question remains why are prices in the two-buyer treatment substantially lower?

Result 2 *Demand withholding per buyer, per period in the two-buyer treatment is not significantly different from that in the four-buyer treatment.*

The observed difference in prices between the two treatments obtains despite the fact that the number of units withheld per buyer, per period was, surprisingly, nearly identical in the two treatments (0.793 in the two-buyer treatment versus 0.766 in the four-buyer treatment). Alternatively, the number of sales lost to demand withholding per buyer per period was, again, nearly identical in the two treatments (0.695 versus 0.698).[12] We cannot reject the hypothesis that the average number of units withheld per buyer, per period in a session (column 5 of Table 1) are the same in the two treatments (the exact p-values from the Wilcoxon-Mann-Whitney tests is .35) nor the hypothesis that the average number of sales lost to withholding per buyer, per period (column 4 of Table 1) are the same in the two treatments (exact p-value=.50). Moreover, the insignificant coefficients on lagged sales lost to withholding interacted with each of the two treatments in regression (2) of Table 2 indicate that withholding does not significantly affect the seller's next-period pricing decision in either treatment, nor does the seller react differently to withholding between treatments (p-value=0.44 in t-test of coefficients).

[12] The number of sales lost to withholding and the number of units withheld are closely related measures, but need not be identical in every period. A difference arises when a buyer withholds a unit of demand and a subsequent buyer in the same period purchases this unit so that the seller does not lose any sales to withholding.

From the similar withholding patterns in the two treatments, it does not necessarily follow that the lower prices in two-buyer markets are irrational. We do not observe the buyers' demand withholding had the monopolist set prices in the two-buyer sessions at the same levels as those in the four-buyer sessions. Perhaps, withholding in the two-buyer sessions would have been appreciably higher at higher prices. As it stands, the monopolists appear as if they have calibrated their prices to equate the levels of withholding in the two treatments. Sales quotas provide one rationale for this calibration: for instance, a sales target of 83% of available capacity is consistent with the observed withholding patterns.

The observed disparity in buyers' as well as sellers' profits as a function of the treatment follows naturally from the first two results. Lower prices and identical withholding levels explain why individual buyers in the two-buyer treatment earned more than those in the four-buyer treatment, while sellers' profits are greater in the four-buyer treatment.

To provide some measure of just how ineffective our posted-offer monopolists are against a small number of buyers, we calculate the index of monopoly effectiveness, M, given by:

$$M = (\pi_A - \pi_C)/(\pi_M - \pi_C),$$

where π_A is actual profit, π_C is competitive profit, and π_M is monopoly profit.

This measure makes possible a comparison of results across experiments with different design parameters by normalizing the monopolist's actual profit by the difference between the theoretical monopoly and competitive profits. For example, a value of $M = 1$ ($M = 0$) would indicate that the seller achieves monopoly (competitive) profits. Based on final period profits, Holt (1995, p. 381) computes this index for six different posted-offer monopoly experiments with different cost structures (decreasing or increasing), buyer types (human or simulated) and regulatory mechanisms. He finds that the index varies from 0.44 (simulated buyers, decreasing costs and a cost-based regulatory mechanism (Harrison, McKee and Rutstrom, 1989)) to 1.0 (human buyers and increasing costs (Smith, 1981)). Like Smith (1981), our experimental design also involves human buyers and increasing marginal costs. However, our index of monopoly effectiveness, also based on final period profits, lies well below the above-reported range. We find $M = -1.88$ in the two-buyer treatment

and $M = 0.005$ in the four-buyer treatment. That is to say, the competitive or even slightly below competitive prices along with some residual withholding lead to profits at or below competitive levels in both our posted-offer monopoly treatments. In section 5, we reconcile previous results with ours.

4.2 Uninformed Treatments

The finding that two buyers achieved lower prices than four buyers has at least two possible sources. First, at equivalent prices, two buyers (would have) withheld more than four buyers such that the monopolist's best response involves offering a price discount to two buyers. We refer to this explanation as the buyer withholding hypothesis. Second, at equivalent prices, the monopolist believes that two buyers will withhold more than four buyers. Given these beliefs, the monopolist best responds by offering a price discount to two buyers. We refer to this explanation as the cautious monopolist hypothesis.

To investigate these two hypotheses, we conducted a second pair of two-buyer (7 experiments) and four-buyer (8 experiments) "uninformed" treatments with marginal cost and demand parameters identical to those employed in the "informed" treatments. The sole difference between the two pairs of treatments is that in the uninformed treatments, the monopolist only was not told how many buyers were in the market; instead, he was told (in both the two-buyer and four-buyer uninformed treatments) that he faced "a small number of buyers, but more than one". Since multiple experiments were conducted simultaneously, monopolists could not infer anything about the number of buyers from the number of people in the room. The monopolist's sales quantity similarly revealed nothing about the number of buyers in the market because the monopolist knew only the aggregate demand curve he faced and not the individual demand curves. Buyers, on the other hand, knew precisely how many other buyers were present along with them in the market and knew that the monopolist did not know the number of buyers in the market.

Since the monopolist only is uninformed, the monopolist's motive for pricing cautiously is removed: the price gap observed between the two informed treatments should disappear in these uninformed treatments and per-buyer withholding should not be significantly different in the two

markets. On the other hand, if the buyer withholding hypothesis explains the price gap between the two informed treatments, then attempts by the monopolist to equate prices in the two uninformed treatments will be met with relatively high levels of withholding in the two-buyer uninformed treatment. For sufficiently high levels of withholding in this treatment, the monopolist may lower his price to assuage the buyers, resulting in lower prices in the two-buyer informed experiments. The end result, according to this hypothesis, may be that the monopolist posts lower prices in the two-buyer uninformed experiments such that the levels of withholding in the two uninformed treatments have been equated, outcomes parallel to those in the two informed treatments.

Result 3 lends initial support to the cautious monopolist hypothesis.

Result 3 *Prices in the two-buyer, uninformed and four-buyer uninformed sessions both start out above, but gradually fall within, the competitive range. Prices in these two treatments are very similar from the beginning of the experiments through the middle rounds. However, in the middle rounds, prices begin to diverge significantly. Prices in the four-buyer sessions remain within the competitive price range, whereas prices in the two-buyer sessions fall below the competitive equilibrium.*

Figure 3 shows that the median prices are very similar through period 14. However, beginning in period 15 prices start to diverge: the median price settles in the competitive range in the four-buyer (4B) treatment, whereas the median price in the two-buyer (2B) treatment falls below the equilibrium price, and continues falling throughout the duration. The results of period-by-period Wilcoxon-Mann-Whitney tests show that we cannot reject the null hypothesis that the two price distributions are the same at the 5% level in any of the first 16 periods. (We can reject the null at the 10% level in periods 11, 15, and 16.) However, the price divergence that begins in period 15 becomes significant at the 5% level in period 17 and increases in significance throughout the remainder of the experiments.

[insert Figure 3 here]

That initial and intermediate prices are indistinguishable in the 2B and 4B uninformed treatments lends support to the cautious pricing hypothesis, namely, observed price differences in the

informed treatments can at least be partially explained by the monopolist pricing more cautiously against two buyers than against four. Once the monopolist does not know how many buyers he faces, the price gap observed in the informed treatments disappears.

It is worth noting that the disappearance of the early price gap between the two uninformed treatments allows us to reject a design-related explanation for the observed price gap in the informed treatments: recall that in order to maintain a constant monopolist-to-individual-buyer profit ratio, interior steps of the monopolist's cost curve were set lower in the two-buyer treatment than in the four-buyer treatment. While this should not matter theoretically, one might argue that, psychologically, this design feature offers the monopolist in the two-buyer treatment a "comfort zone" below the competitive price that doesn't exist in the four-buyer treatment. The finding that the price gap in the uninformed treatments disappears, even though the demand and cost configurations were common knowledge in all treatments, allows us to reject this explanation.

Having observed similar prices in the two treatments through the middle rounds, the cautious monopolist hypothesis also predicts similar withholding behavior. Result 4 confirms this prediction.

Result 4 *The overall aggregate quantities of demand withholding and sales lost to demand withholding are identical in the uninformed two-buyer and four-buyer treatments. Furthermore, the distributions over time of these withholding measures are not significantly different for the vast majority of rounds of play. Only in the late rounds do marginally significant differences between the two treatments appear.*

The number of units of demand withheld per buyer, per period is 0.821 in the 2B, uninformed treatment compared to 0.824 units in the 4B, uninformed treatment (Wilcoxon-Mann-Whitney $z=-0.167$, p-value=.87 where a buyer's average withholding over the entire session is treated as an independent observation). Similarly, the number of sales lost to demand withholding per buyer, per period is 0.744 units in the 2B treatment compared to 0.774 in the 4B treatment (Wilcoxon-Mann-Whitney exact p-value=.35).

Moreover, an examination of the distribution of demand withholding over the 30 periods by treatment reveals strong similarities between the treatments. Figure 4 plots the average per period

sales lost to withholding for the uninformed 2B and 4B treatments. Sales lost to withholding start out at low levels in both treatments (0.2 units on average). Withholding quickly intensifies and remains at relatively high levels beyond round 20 when, in both treatments, withholding begins to decay. Results from the Wilcoxon-Mann-Whitney test reveal that only in period 22 are the distributions of average sales lost to withholding significantly different at the 5% level. (In periods 21, 23, 25 and 27, the difference is significant at the 10% level.)

[insert Figure 4 here]

Taken together, Results 3 and 4 support the cautious pricing hypothesis: the observed difference in initial pricing in the informed treatments can be attributed to the monopolist pricing more tentatively when confronted with only two buyers. When the number of buyers is unknown to the monopolist, Result 3 shows that the initial price differential disappears. Had buyers in the 2B treatment withheld less than those in the 4B treatment, for instance, the monopolist's initial pricing behavior could perhaps be explained, in part, by a response to the observed withholding behavior in the two treatments. This confound however is not present in our data. The finding that the withholding behavior is identical in the two treatments (Result 4) therefore strengthens our conclusion that the lower pricing in the two-buyer informed treatment follows simply from the monopolist's more cautious reaction to two buyers.[13]

4.3 Pricing Over Time

To gain additional insights into the monopolist's pricing behavior we estimated a first-differences model in which both the price and the number of units withheld at time $t-1$ are used to explain the pricing decision at time t. We report results from the two-step estimator of Anderson and Hsiao (1980), which uses lags of variables as instruments for the lagged dependent variable on the

[13] Our support for the cautious monopolist hypothesis is in the spirit of a conjecture raised by Davis and Williams (1991). They test whether seller market power might inhibit convergence to the competitive equilibrium. Prices exceed the competitive equilibrium by at least \$0.30 in each of their four simulated-buyer experiments, while only one of four human-buyer experiments deviates from the competitive price. They conclude that "...computer-simulated buyers may generate qualitatively different results than similar posted-offer markets using human buyers, even if human buyers fully reveal demand. Posted-offer sellers appear initially to employ more tentative strategies when facing human buyers than when facing simulated buyers. This conjecture bears further analysis." (p. 273)

right-hand side of the model. The estimator controls for the fact that least squares estimates are biased in dynamic panel models.

The regression model is:

$$p_{it} = \beta_1 p_{it-1} + \beta_2 W_{it-1} + \beta_3 4BInf + \beta_4 4BUninf + \beta_5 2BUninf + n_i + v_{it},$$

where p_{it} and p_{it-1} represent the price that monopolist i sets at time t and $t-1$ respectively; W_{it-1} represents the number of sales lost to withholding at time $t-1$; $4BInf$ is a dummy variable that represents the four-buyer informed sessions, $4BUninf$ represents the four-buyer uninformed sessions, and $2BUninf$ represents the two-buyer uninformed sessions; n_i is a time invariant individual effect, and v_{it} is seller i's error at time t. The model is first differenced to remove the unobserved individual effects, and the treatment dummies are added after differencing. Hence the dummy variables test for a difference between experimental treatments in pricing *trends*, not levels. This yields the following specification:

$$\Delta p_{it} = \beta_1 \Delta p_{it-1} + \beta_2 \Delta W_{it-1} + \beta_3 4BInf + \beta_4 4BUninf + \beta_5 2BUninf + \Delta v_{it},$$

where Δ represents the difference operator so that, for example, $\Delta p_{it} = p_{it} - p_{it-1}$. The Anderson and Hsiao (1980) instrumental variable estimator uses a set of instruments, which are taken from the set of lagged explanatory variables, to correct for the endogeneity of Δp_{it-1}. An important choice of instruments is whether to use the level p_{it-2} or the difference Δp_{it-2}. Arellano and Bond (1991) show that the level instrument p_{it-2} yields better finite sample properties, thus we use it but report the sensitivity of the results to other choices of instruments. We test the robustness of the specification by testing both one-step and two-step estimators. We report results from a two-step Anderson and Hsiao (1980) type instrumental variable estimator using ΔW_{it-2}, ΔW_{it-1}, and p_{it-2} as instruments for Δp_{it-1}. For the regressions we used the dynamic panel data module in PcGive Professional (Hendry and Doornik, 2001). We base our inferences on results that are robust to these different specifications.

[insert Table 3 here]

Table 3 presents the regression results. There are 770 total observations (two cross sections are lost in constructing lags and first differences). The regression passes specification tests: a Wald test of the joint significance of the regressors is significant at better than the 1% level ($\chi^2 = 11.23$, $df = 2$), the Sargan tests accepts the lack of serial correlation in the errors, and AR(1) and AR(2) specification tests are passed. The asymptotic standard errors we report are robust to general cross-section and time-series heteroskedasticity.

The positive but small and significant coefficient on the lagged dependent variable indicates a small sensitivity to past pricing decisions. The negative and significant coefficient on the previous period's lost sales to withholding indicates that the monopolists are influenced by the buyers' demand withholding decisions in a logical manner: an increase in the number of lost sales to withholding results on average in a lower price in the next period. The only treatment dummy variable that may be significant is for the two-buyer uninformed sessions: the negative coefficient, with a p-value of 0.073, indicates that the trend in pricing in the two-buyer uninformed sessions is negative compared with the two-buyer informed sessions.

To test for the robustness of our model specification, we repeated the exercise using a one-step estimator. We then added to our set of instruments the first difference of the second lag of the dependent variable (Δp_{it-2}) and repeated both the one-step and two-step estimations. All of the findings reported in Table 3 hold across specifications except for the significance of the two-buyer uninformed dummy variable. Since this result is not unambiguously robust to reasonable differences in the model's specification, we conclude that we cannot reject the null hypothesis that pricing trends are the same in the different experimental treatments.

These regressions shed further light on the monopolist's reaction to buyer withholding, the information level and the number of buyers in the market. First, as may be expected, withholding decisions affect the dynamics of the pricing decisions across experimental treatments: sellers respond to withholding by lowering the next-period price in proportion to the increase in units withheld.[14] Second, the pricing dynamics appear largely insensitive to experimental treatment. Thus, the

[14] Compare this highly significant result with the almost marginally significant impact of the amount of withholding on the next-period price in regression (2) of Table 2. The implication is that the level of withholding is less meaningful for monopolist pricing than the change in withholding from one period to the next in response to price changes.

presence of fewer buyers, when known to the monopolist, brings about immediate price concessions; however, once these concessions are in place, we find no strong evidence that the monopolist's pricing dynamics differ across treatments. This result is consistent with the cautious monopolist hypothesis.

5 Discussion

5.1 The Behavioral Salience of the Experimental Design

Our main result reveals that two buyers achieve significantly lower prices than four buyers against a monopolist. Along the way, we observed considerable buyer demand withholding and competitive or even below competitive pricing, two findings that need to be reconciled with the more usual observations of inactive buyers and monopoly or near-monopoly pricing in posted-offer markets. At the other extreme, Smith's (1981) posted-offer monopoly session reveals quick convergence to the monopoly price and no units of demand withheld by any of the five buyers.

These disparate findings highlight the importance of the underlying cost and demand parameters and the information conditions. In Smith's private-information experiment, each of the five buyers possessed only a single unit of demand, making withholding very costly. Moreover, the monopolist earned ten times as much as each buyer at the monopoly price and only twice as much at the competitive price, and even these relatively mild inequalities were unknown to market participants who observed the costs or values of their own units only. By comparison, each buyer possesses four units of demand in our design. At the monopoly price, a buyer earns 15 units on the first purchase and 0 profit on the next two purchases. The monopolist, by contrast, earns 550 units in the two-buyer treatment and 640 in the four-buyer treatment, resulting in profit ratios of 36.66:1 and 42.66:1 in favor of the monopolist. However, a buyer can costlessly withhold two units of demand to reduce the monopolist's profit to 400 units in the two-buyer case and to 540 units in the four-buyer case, yielding a more modest 6:1 profit ratio in both treatments. Given the common knowledge of the underlying parameters along with a mild concern for fairness, buyers will withhold at the monopoly price. To avoid costly withholding, the monopolist lowers price to the competitive

range.

In summary, the buyers' ability to punish the monopolist cheaply and effectively renders the monopoly price unlikely. Thus, throughout the paper we have emphasized the observed price differential between the two-buyer and four-buyer treatments, rather than the price levels. One avenue for future research would be to design an experiment more germane to the monopoly outcome to pit monopoly power against buyer countervailing power.

5.2 An Application to Increasing Industrial Concentration

Fuelled primarily by an ongoing horizontal merger wave, industrial concentration in the U.S. has increased over the past two decades and is expected to continue to increase over at least the decade to come (see Pryor, 2001). According to our results in a laboratory environment that trades off realism for control, rising industrial concentration needn't necessarily be a cause for concern: one must probe on an industry-by-industry basis whether a rise in concentration constitutes an increase in the original or the countervailing market power. As a case in point, Dobson and Waterson (1997) claim that U.K. competition authorities seem to be alert to the potential role of countervailing power. They report evidence from the U.K. of increased concentration in the retail sector, contrasted with declining concentration in manufacturing in recent years. In spite of the former, Dobson and Waterson argue that "U.K. competition authorities have remained largely impassive toward this increase in concentration" (p. 418), and that they have taken a "benign view of consolidation in retailing ... in contrast to the position adopted in the United States ... [Consequently,] U.S. concentration levels in retailing have generally risen at a much slower pace than in the United Kingdom" (p. 419).

One unanswered question is, are the reduced prices achieved by the consolidated U.K. retailers passed on to final consumers? One interpretation of the U.K.'s passivity toward retailer consolidation is that they believe this to be the case. The same question may well asked in our setup. Two buyers in our experiments achieved significantly lower prices than four buyers. Do atomistic, final consumers ultimately benefit from these lower prices? Theoretical models by von Ungern-Sternberg (1996) and Dobson and Waterson (1997) show that whether powerful buyers pass on cost savings to

final consumers depends on the degree of competition between these intermediate buyers as sellers in the final-product market.

What is for certain is that these lower prices have come at the expense of reduced market efficiency. Through demand withholding (the only strategic action at the disposal of posted-offer buyers), buyers forced prices down. Similar price levels in more symmetric market institutions such as the double-auction or pit market, the bilateral negotiation institution (Cason et al., 2003) or the multilateral negotiation institution (Thomas and Wilson, 2002) needn't compromise efficiency. The possibility of repeated price negotiations in these market institutions can generate lower prices. It remains to be seen whether such prices can indeed be obtained in these institutions. On the one hand, buyers' enlarged space of available actions associated with these market mechanisms favors lower prices compared to the posted-offer market. On the other hand, the ease with which posted-offer buyers can commit to not buying in a given period and the costliness of this action to the posted-offer monopolist encourages him to slash his price in the next period. In real-time double auction or pit markets, for instance, patience or, at best, a modest price reduction may be the monopolist's response to a buyer's refusal to accept his ask price. Examining the impact of buyer concentration in these more symmetric market institutions that more closely resemble the bargaining structure typical of intermediate product markets is another promising direction for this research agenda.

6 Conclusion

We designed a series of experiments to examine the impact of buyer concentration on seller pricing. On the one hand, we presented buyers with an onerous task: buyers face an increasing-cost monopolist, are unable to collude or even signal their actions to others and are limited to accepting or rejecting posted prices. On the other hand, in an effort to induce at least some buyers to reject profitable purchases, we designed our experiments to include a substantial surplus inequality between the monopolist and individual buyers at the monopoly and the competitive prices. Indeed, we observe substantial variation among buyers in their withholding patterns. However, in the aggregate,

buyers withhold demand to the same extent in the two-buyer and four-buyer treatments.

Notwithstanding, we find that two buyers achieve significantly lower prices than four buyers. By manipulating the monopolist's information, we are able to identify the source of the price gap. When the monopolist (but not the buyers) is uninformed about the number of buyers in the market, the price gap between the two-buyer and four-buyer treatments disappears. As a result, we are able to attribute lower pricing in the informed two-buyer treatment to the monopolist's cautious or conservative pricing for fear of provoking costly withholding. Put differently, the monopolist appears to place a higher subjective probability on buyers withholding demand above a given price threshold in the informed two-buyer treatment than the informed four-buyer one. Therefore, to avoid triggering this price threshold in the two-buyer sessions, he offers a lower price.

Our experimental parameters were chosen so that the monopoly (and even competitive) prices are identical in the markets with two and four buyers. Thus, according to the theory, the number of buyers should play no role in the take-it-or-leave prices set by the monopolist. By contrast, our results provide the basis for a behavioral theory of buyer countervailing power. For example, "reputation effects" as in Kreps et al. (1982) might account for withholding behavior in early periods of the game. Moreover, sellers' immediate reaction to the number of buyers before any game history is observed in the informed treatments offers evidence that the number of buyers may be a useful parameter in such a theory.

References

[1] Anderson, T. W. and Cheng Hsiao (1980) "Formulation and estimation of dynamic models using panel data," *Journal of Econometrics*, 18:1, 47-82.

[2] Arellano, Manuel and Stephen Bond (1991) "Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations," *Review of Economic Studies*, 58, 277-297.

[3] Bertrand, Joseph (1883) "Review of Theorie Mathematique de la Richesse Sociale and Recherches sur les Principes Mathematiques de la Theorie des Richesse," *Journal des Savants*, 499-508.

[4] Brown-Kruse, Jamie (1991) "Contestability in the presence of an alternate market: an experimental investigation," *RAND Journal of Economics*, 22:1, 136-147.

[5] Cason, Timothy N., Daniel Friedman and Garrett H. Milam (2003) "Bargaining versus Posted Price Competition in Customer Markets," *International Journal of Industrial Organization*, 21, 223-251.

[6] Cason Timothy N. and Arlington W. Williams (1990) "Competitive Equilibrium Convergence in a Posted-Offer Market with Extreme Earnings Inequalities," *Journal of Economic Behavior and Organization*, 14, 331-352.

[7] Coursey, Don, R. Mark Isaac and Vernon L. Smith (1984) "Natural Monopoly and Contested Markets: Some Experimental Results," *Journal of Law and Economics*, 27, 91-113.

[8] Davis, D. and A. Williams (1991) "The Hayek Hypothesis in Experimental Auctions: Institutional Effects and Market Power," *Economic Inquiry*, 29, 261-274.

[9] Davis, Douglas D. and Bart J. Wilson (2004) "Horizontal Mergers, Strategic Buyers and Fixed Cost Synergies: An Experimental Investigation," unpublished manuscript.

[10] Dobson, Paul W. and Michael Waterson (1997) "Countervailing Power and Consumer Prices," *Economic Journal*, 107, 418-430.

[11] Dufwenberg, Martin and Uri Gneezy (2000) "Price competition and market concentration: an experimental study," *International Journal of Industrial Organization*, 18, 7-22.

[12] Galbraith, John Kenneth (1952) *American Capitalism: The Concept of Countervailing Power*, Houghton Mifflin: Boston, MA, chapter 9.

[13] Harrison, Glenn W., Michael McKee and Elisabet E. Rutstrom (1990) "Experimental Evaluation of Institutions of Monopoly Restraint," in *Advances in Behavioral Economics*, L. Green and J. Kagel (eds.), vol. 2, Ablex Publishing Co.: Norwood, NJ.

[14] Hendry, David F. and Jurgen A. Doornik (2001) *Empirical Econometric Modelling Using PcGive*, Volume 1, 3rd Edition, Timberlake Consultants Ltd.: London.

[15] Hoffman, Elizabeth, Kevin McCabe, Keith Shachat and Vernon Smith (1994) "Preferences, Property Rights and Anonymity in Bargaining Games," *Games and Economic Behavior*, 7, 346-380.

[16] Holt, Charles A. (1995) "Industrial Organization," in *The Handbook of Experimental Economics*, J. H. Kagel and A. E. Roth (eds.), Princeton University Press: Princeton, NJ.

[17] Holt, Charles A. (1989) "The Exercise of Market Power in Laboratory Experiments," *Journal of Law and Economics*, 32, S130-S137.

[18] Huck, Steffen, Hans-Theo Normann and Jörg Oechssler (2004) "Two are Few and Four are Many: On Number Effects in Cournot Oligopoly," *Journal of Economic Behavior and Organization*, 53, 435-446.

[19] Hunter, Alex (1958) "Notes on Countervailing Power," *Economic Journal*, 68:269, 89-103.

[20] Isaac, R. Mark and Stanley Reynolds (2002) "Two or Four Firms: Does It Matter," in *Research in Experimental Economics*, (C. Holt and R.M. Isaac, eds.), vol. 9, JAI-Elsevier: Amsterdam.

[21] Mestelman, Stuart and Douglas Welland (1988) "Advance Production in Experimental Markets," *Review of Economic Studies*, 55:4, 641-654.

[22] Normann, Hans-Theo, Bradley J. Ruffle and Christopher M. Snyder (2005) "Do Buyer-Size Discounts Depend on the Curvature of the Surplus Function? Experimental Tests of Bargaining Models," Ben-Gurion University WP 03-07.

[23] Plott, Charles R. and Vernon L. Smith (1978) "An Experimental Evaluation of Two Exchange Institutions," *Review of Economic Studies*, 45:1, 133-153.

[24] Pryor, Frederic L. (2001) "New Trends in U.S. Industrial Concentration," *Review of Industrial Organization*, 18, 301-326.

[25] Ruffle, Bradley J. (forthcoming) "Buyer Countervailing Power: A Survey of the Theory and Experimental Evidence," in *Experiments and Antitrust Policy*, J. Hinloopen and H.-T. Normann (eds.), Cambridge, U.K.: Cambridge University Press.

[26] Ruffle, Bradley J. (2000) "Some factors affecting demand withholding in posted-offer markets," *Economic Theory*, 16:3, 529-544.

[27] Scherer, Frederic M. and David Ross (1990) *Industrial Market Structure and Economic Performance*, 3rd ed., Houghton Mifflin: Boston, MA.

[28] Smith, Vernon L. (1981) "An Empirical Study of Decentralized Institutions of Monopoly Restraint," in *Essays in contemporary fields of economics in honor of E.T. Weiler (1914-1979)*, J. Quirk and G. Horwich (eds.), Purdue University Press: West Lafayette, IN, pp. 83-106.

[29] Stigler, George J. (1954) "The Economist Plays with Blocs," *American Economic Review*, 44, 7-14.

[30] Stiglitz, Joseph E. (1987) "Competition and the Number of Firms in a Market: Are Duopolies More Competitive than Atomistic Markets?" *Journal of Political Economy*, 95:5, 1041-1061.

[31] Thomas, Charles J. and Bart J. Wilson (2002) "A comparison of auctions and multilateral negotiations," *RAND Journal of Economics*, 33:1, 140-155.

[32] von Ungern-Sternberg, T. (1996) "Countervailing Power Revisited," *International Journal of Industrial Organization*, 14, 507-520.

Table 1: Summary Statistics for the Two-Buyer and Four-Buyer Informed Experiments

Experiment	Median Posted Price	Mean Efficiency	No. of Sales Lost per Buyer-period	No. of Units Withheld per Buyer-period	Mean Buyer Profit per Period	Mean Monopolist Profit per Period
(1)	(2)	(3)	(4)	(5)	(6)	(7)
2B4	0.05	0.80	0.32	0.32	0.52	4.09
2B5	0.035	0.83	0.62	0.62	0.60	4.09
2B2	0	0.55	1.30	1.30	0.61	2.28
2B1	-0.02	0.91	0.43	0.43	0.72	4.38
2B6	-0.21	0.84	0.63	0.70	1.20	3.12
2B3	-0.25	0.74	0.52	0.82	1.14	2.44
2B7	-0.275	0.69	1.05	1.37	1.09	2.24
Overall Two-buyer	-0.07 (0.35)	0.764 (0.222)	0.695 (0.735)	0.793 (1.17)	0.84 (0.51)	3.21 (1.19)
4B13	0.19	0.69	0.78	0.91	0.32	4.21
4B14	0.19	0.68	0.61	0.61	0.23	4.54
4B9	0.165	0.74	0.52	0.53	0.11	5.43
4B12	0.04	0.90	0.41	0.46	0.67	4.57
4B15	0.04	0.75	0.85	0.87	0.49	4.01
4B8	0.025	0.80	0.64	0.69	0.58	4.09
4B11	0	0.72	0.92	1.09	0.66	3.16
4B10	-0.015	0.73	0.71	0.82	0.67	3.18
Overall Four-buyer	0.12 (0.59)	0.755 (0.204)	0.698 (0.542)	0.766 (1.02)	0.48 (0.41)	4.14 (1.40)

Session-level summary statistics arranged in descending order by median posted price (column (2)). For each statistic, the overall treatment average is also reported (standard deviation in parentheses).

Table 2: OLS Panel Regressions

Variable	Description	Coefficient (Std. Error) (1)	(2)
p_{it-1}	monopolist's price at t-1	0.0714 (0.0566)	0.0718 (0.0565)
W_{it-1}	sales lost to withholding at t-1	-0.0080 (0.0046)	---
W_{it-1}*2BInf	sales lost to withholding at t-1 in 2B informed treatment	---	-0.0143 (0.0117)
W_{it-1}*4BInf	sales lost to withholding at t-1 in 4B informed treatment	---	-0.0049 (0.0036)
4BInf	4 Buyer Informed	0.1604*** (0.0466)	0.1421** (0.0611)
last5*2BInf	last 5 periods in 2 Buyer Informed	-0.0122 (0.0357)	-0.0144 (0.0391)
last5*4BInf	last 5 periods in 4 Buyer Informed	-0.0486** (0.0166)	-0.0462** (0.0161)
Constant		-0.0736 (0.0455)	-0.0643 (0.0536)
adjusted R^2		0.289	0.287

Dependent Variable: p_{it}

*** p-value less than .01
** p-value less than .05
* p-value less than .10

OLS regressions on the seller's period t price in the informed treatments only. Standard errors in parentheses correct for heteroskedasticity and possible correlation across periods played by the same seller.

Table 3: Dynamic Panel Regression Estimates

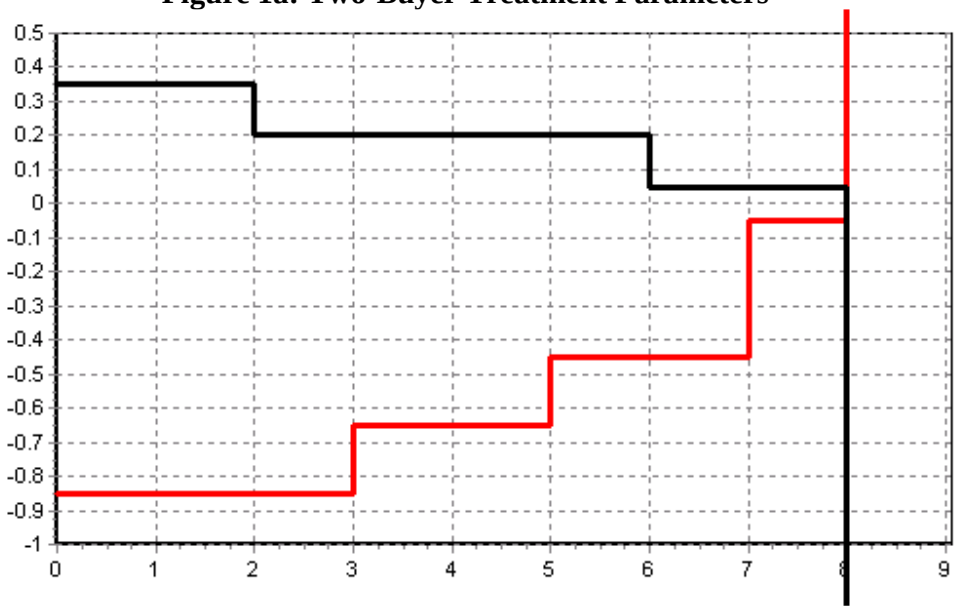
Variable	Description	Coefficient (Std. Error)
Δp_{it-1}	Price	0.0111** (0.005)
ΔW_{it-1}	Units Withheld	-0.0044*** (0.002)
4BInf	4 Buyer Informed	0.0006 (0.002)
4BUninf	4 Buyer Uninformed	-0.0003 (0.002)
2BUninf	2 Buyer Uninformed	-0.0054* (0.003)
Constant		-0.0026 (0.0018)

Dependent Variable: $p_{it} - p_{it-1}$

*** p-value less than .01
** p-value less than .05
* p-value less than .10

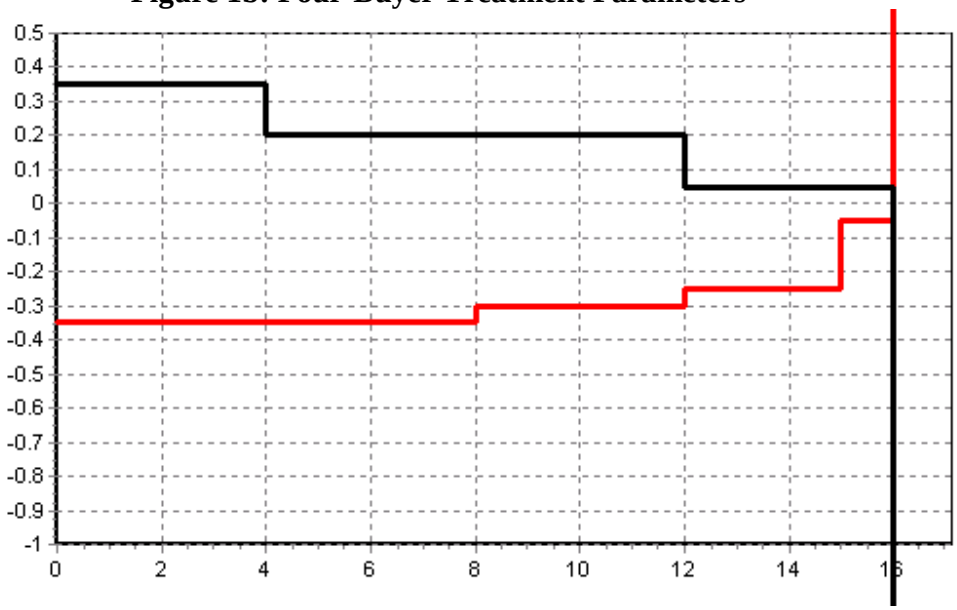
Dynamic panel regressions on the pooled data from the informed and uninformed treatments**.**

Figure 1a: Two-Buyer Treatment Parameters



The monopolist's marginal cost and the buyers' demand curve in the two-buyer experiments. The competitive price range lies in the interval between the prices –0.05 and 0.05. All costs and valuations are expressed as deviations from the midpoint of the competitive price range, which is normalized to 0. Each of the two symmetric buyers possesses four units of demand, the first unit of which is valued at +0.35, the second and third units have values of +0.20 each, and the fourth unit has a value of +0.05.

Figure 1b: Four-Buyer Treatment Parameters



The monopolist's marginal cost and the buyers' demand curve in the four-buyer experiments. The competitive price range and individual buyers' demand curves are identical to the two-buyer treatment. All costs and valuations are expressed as deviations from the midpoint of the competitive price range.

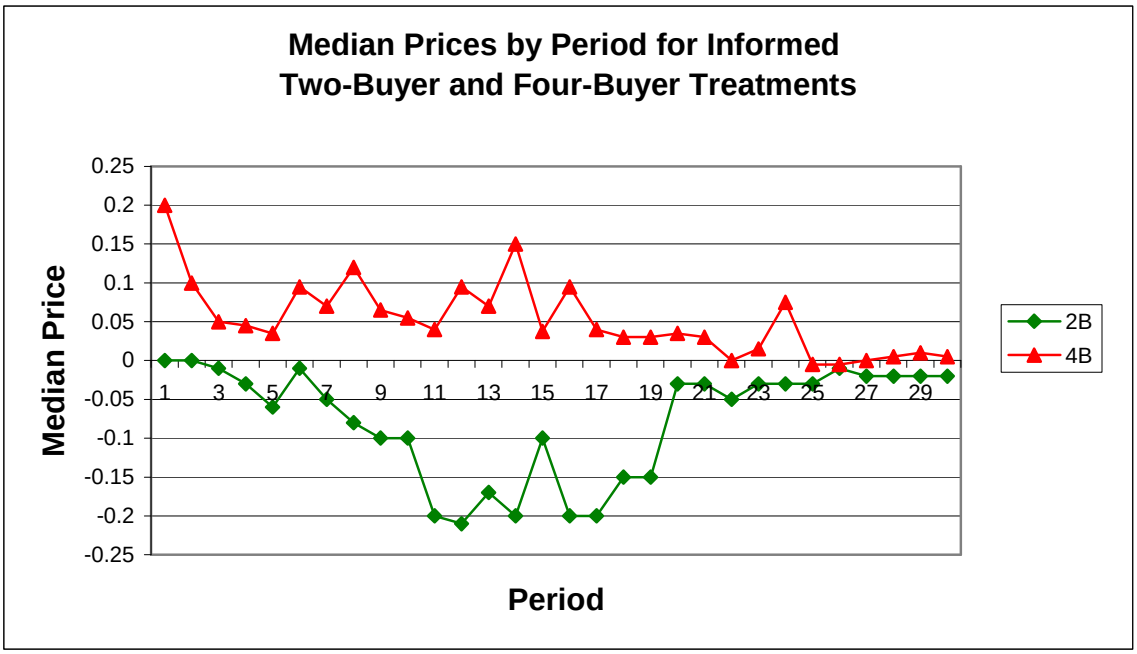


Figure 2: Median price series for the 7 two-buyer experiments (2B) and 8 four-buyer (4B) experiments in which the monopolist knew precisely how many buyers he faced.

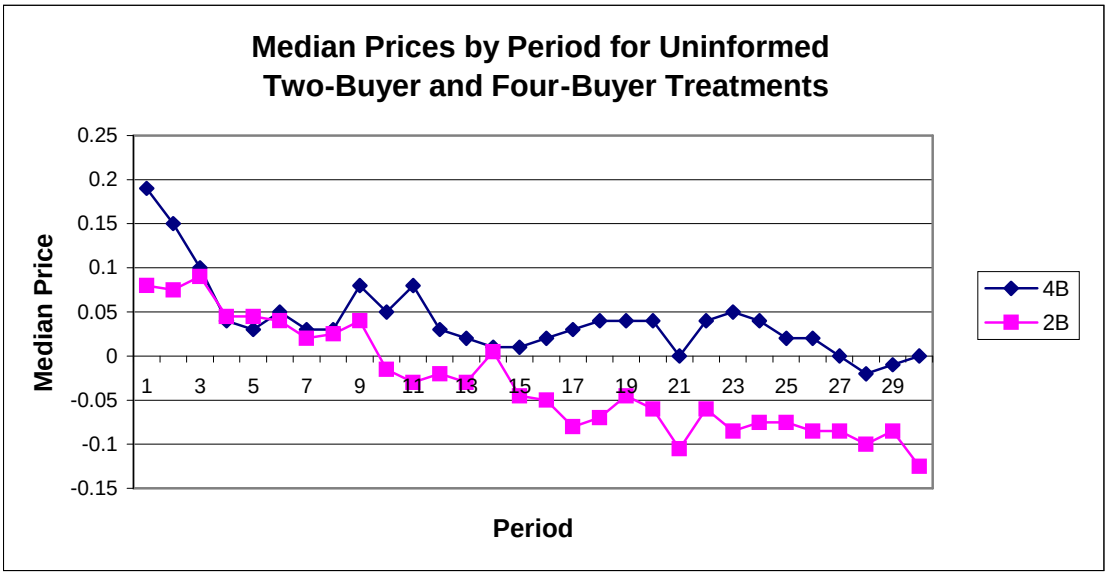


Figure 3: Median price series for the 7 two-buyer (2B) and 8 four-buyer (4B) experiments in which the monopolist did not know how many buyers he faced.

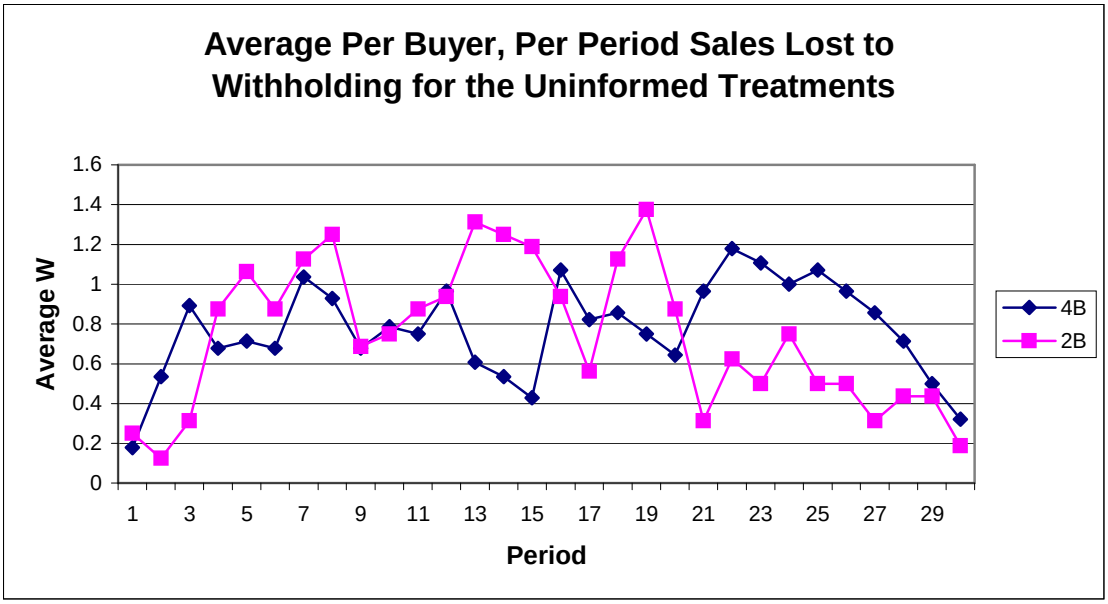


Figure 4: Times series plots for the per buyer, per period sales lost to demand withholding averaged over all of the experiments in each of the two uninformed treatments in which the monopolist did not know how many buyers he faced.