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List Prices and Discounts: The Interrelationship between Consumer Shopping Patterns and Profitable Marketing Strategies

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ABSTRACT

This article illustrates the importance of shopping and marketing strategies when the price-setting institution typically used to model retail exchange is modified to allow buyer-specific discounts from the list price. Unlike the simple price-setting game, a variety of shopping and marketing strategies can be rational in this more complex setting. Moreover, different strategy combinations yield distinct predictions: Equilibrium prices may either essentially match those predicted in the absence of discounts, or they may be at the collusive level. Data from laboratory markets with discount opportunities similarly indicate two distinct strategy-dependent behavioral outcomes. © 1996 John Wiley & Sons, Inc.

Many elements fundamental to the study of marketing have been treated largely as matters of secondary importance in traditional industrial organization theory. For example, aside from a constraint that consumer and producer choices be consistent with rationality, both the

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psychological factors affecting consumer shopping patterns and the marketing strategies chosen by firms have typically been ignored.

However, the relatively recent shift toward game-theoretic and experimental methods in industrial organization economics has led to an increased focus on the institutional characteristics defining market exchange. In turn, this increased attention to institutional detail has fostered a new appreciation for the importance of factors such as shopping preferences and marketing strategies. The reason is straightforward. When market interactions are formally modeled as a game, a variety of behavioral patterns are often consistent with rationality. Although the choice of these patterns is often a matter of psychology or preference, price and profit predictions can hinge on the patterns selected by consumers and producers.

Consider, for example, trading where sellers publicly post list prices. Institutions of this type characterize a wide variety of retail situations. Markets with public list prices account for a considerable volume of trade in the United States each year, and have long been the focus of investigation by economists. Such markets have traditionally been analyzed in the context of a model of price competition first formulated by Bertrand (1883). Seller and buyer strategies in the Bertrand model are simple and mechanical: Sellers, who compete only on the basis of price, must undercut their competitors in order to make any sales. Buyers, who make decisions only on the basis of the listed prices are concerned only with making a purchase at the lowest posted price. The interaction of these strategies generates a prediction that the market will generate competitive prices and quantities consistent with the intersection of market supply and demand arrays.

The standard Bertrand model does not allow sellers to discount from their listed prices. In many naturally occurring markets, however, buyers ask for and often receive price concessions. Selective discounting is a common feature in negotiations for major consumer goods, such as housing and automobiles. Producer goods are also sold at discount, particularly when the number of buyers is not large. Indeed, discounting is so widespread in producer goods markets that the absence of sales below list prices is considered unusual. For example, the infrequency of discounts was one of the factors that triggered a Federal Trade Commission investigation of pricing practices of lead-based gasoline additive producers (FTC Docket No. 9128).

Once discounting possibilities are introduced, both consumer shopping patterns and seller marketing strategies play a critical role in determining price and sales predictions. As simple intuition suggets, the ability to offer private, selective discounts makes a market more competitive; given any set of publicly posted prices, competing sellers will feel compelled to offer private discounts on any public posting above the lowest. Private discounting opportunities may also impede the implementation and maintenance of conspiracies, as such opportunities

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make it difficult for sellers to distinguish price shading by a rival from demand shocks or strategic buyer refusals to purchase.

But discounting may make a market *less* competitive. Suppose, for example, that buyers shop first from the seller listing the highest price, reasoning that this seller will be most likely to grant a sufficiently large discount to stay competitive. In this case, a high list price may actually increase a seller's potential sales volume, and having the higher price may be more profitable if the discounts needed to satisfy buyers are not too great. This suggests that discounting may *raise* list prices, because the disadvantage of being the high-price firm is mitigated if competitors' prices can be matched in the discounting phase. Moreover, if all sellers have an incentive to raise their list prices, it is plausible that collusive (joint-profit-maximizing) prices may be the outcome in a noncooperative equilibrium.

The purpose of this article is to use game-theoretic and experimental methods to demonstrate the centrality of shopping and marketing strategy choices to both predicted and observed outcomes. Although existing research is limited, it bears mentioning that this is not the first investigation of discounting in economics. Relevant theoretical models include Varian (1980), Holt and Scheffman (1987) and Seidmann (1990). Related experimental work includes Grether and Plott (1984), who investigated elements of the above-mentioned *Ethyl* case, and Hong and Plott (1982). The present investigation is unique in its focus on the effects of shopping strategy choices on equilibria.

Theoretical Considerations

In this section a simple market structure is constructed to illustrate some of the possible effects of providing sellers with the option of offering selective discounts. The model is stylized, and the analysis is specific to the supply-and-demand arrays employed. Rather than generality, the purpose of this discussion is to illustrate the basic incentive changes that discounting opportunities can create.

Consider the market structure represented in Figure 1. This market is composed of two sellers, denoted *S1* and *S2*, and three buyers, denoted *B1*, *B2*, and *B3*. Aggregate supply consists of eight units, equally divided between the sellers. Each seller may offer two units at a low cost level, c_L, and two units at a higher cost level, c_H. Aggregate demand consists of nine units, three for each buyer. Each buyer has a high reservation value, r_H, for their first two unit(s) purchased, and a lower reservation value r_L for their third unit. (At present, ignore the demand step constructed with a thin line above r_H in Figure 1.) It is apparent from Figure 1 that in the competitive equilibrium defined by the intersection of market demand and supply curves, the price is r_L and the quantity is eight units. The market will be organized under variants of what has been termed *posted-offer* trading rules. That is,

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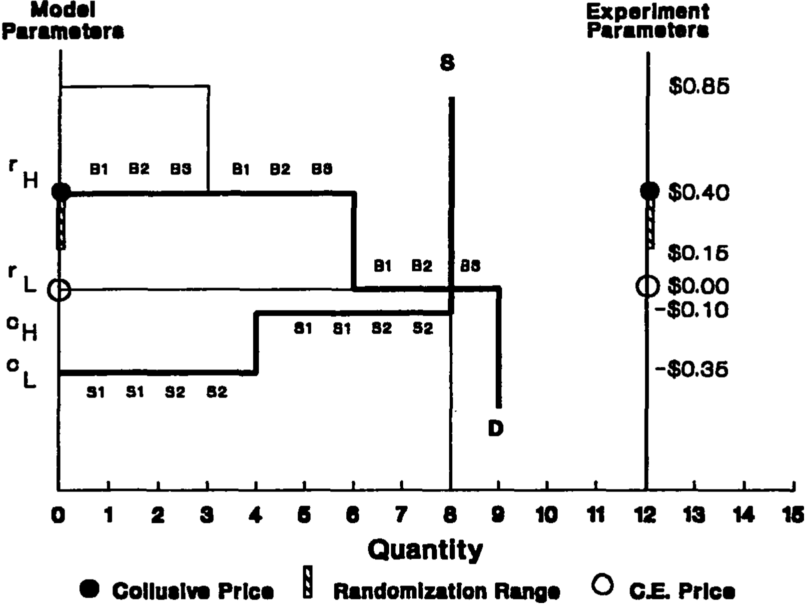

Figure 1 Supply and demand arrays.

in the no-discounting case, sellers simultaneously post prices that are publicly displayed to the market. Buyers then are given the opportunity to make purchases from the sellers at the posted prices on a take-it-or-leave-it basis. Consider now the static equilibria for this market, first when discounting is not possible, then when it is possible.

Price Competition without Discounting. In noncooperative game theory the notion of an equilibrium is developed in terms of strategies that are stable or self-sustaining. The most basic equilibrium concept is that of a *Nash equilibrium*, which occurs when no player would find it profitable to unilaterally deviate from some combination of strategies employed by that player in conjunction with all the other players. In the current context, for a wide variety of parameter choices the competitive equilibrium is not a Nash equilibrium. For all prices in the range between r_L and r_H, in this market, buyers demand six units, and each seller can only provide a maximum of four units. Thus, provided that sellers' units with a cost of c_H are not too profitable, either seller may increase profits from the competitive level (on the sale of four units at r_L) by raising the price to r_H and selling only their two low-cost units. Sellers in capacity-constrained market designs who find unilateral increases from the competitive price prediction profitable are said to possess *market power* (Holt, 1989; Holt & Solis-Soberon, 1991).

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In fact, when sellers possess market power in this sense, no collective combination of prices satisfies the Nash equilibrium criterion. Consider the joint-profit-maximizing (monopoly) outcome with each firm selling three units at a price r_H. This outcome is not an equilibrium, because each firm has an incentive to undercut the other and sell all four units, which yields earnings just slightly below $(2r_H - c_L) + 2(r_H - c_H)$. Incentives to price shade similarly rule out common price equilibria over a range of prices below r_H down to a lower price $\underline{p}$, where earnings from being the lowest price seller no longer exceed security earnings at the limit price. Formally, $\underline{p}$ is the price such that the earnings from selling four units with a price cut to $\underline{p}$ are equal to the earnings from only selling two units with a price increase to the demand intercept r_H: $2(\underline{p} - c_L) + 2(\underline{p} - c_H) = 2(r_H - c_L)$. Thus $\underline{p}$ is the average of r_H and c_H. But this lower bound $\underline{p}$ cannot be an equilibrium price, because at a common price of $\underline{p}$, expected sales for each seller are only three units, and either seller could increase expected profit by cutting price a little in order to sell four units.

Rather, the only equilibrium for this game occurs when sellers pick randomly from a price distribution. Nash equilibria of this sort are termed *mixed-strategy equilibria*. A symmetric, mixed-strategy equilibrium exists over the range from r_H to $\underline{p}$. (This range is represented in Figure 1 as a shaded bar on the vertical Model Parameters axis.) In a mixed-strategy equilibrium, expected profits for each seller must remain constant over the entire range of randomization (because the firm would be unwilling to choose randomly if expected profits were not equal on this range). The equilibrium is identified by finding a reference point for earnings at some point in the randomization range, and by then calculating the pricing distribution function that one seller must follow in order to keep expected profits constant for the other seller. A reference point for earnings is usually found at some boundary of the range. In this case, earnings may be anchored at the upper bound of the randomizing distribution r_H, where sellers are certain to sell two units and earn security earnings of $2(r_H - c_L)$. The equilibrium pricing distribution is then calculated as follows. Let $G(p)$ be the probability that a price of p will be the higher of the two prices in the mixed equilibrium. A seller posting the higher of the two prices sells two units and earns $H(p) = 2(p - c_L)$. The seller with the lower price sells all four units and earns $L(p) = 2(p - c_L) + 2(p - c_H)$. Assuming risk neutrality, for any price p on $[\underline{p}, r_H]$, expected earnings are:

$$G(p)H(p) + (1 - G(p))L(p). \tag{1}$$

If one equates this expected earnings expression with the security earnings of $2(r_H - c_L)$, one can solve for $G(p)$:

$$G(p) = (2p - r_H - c_H)/(p - c_H). \tag{2}$$

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The equilibrium characterized by $G(p)$ is the unique Nash equilibrium for the stage game. It may be readily verified that the equilibrium distribution function in (2) has a value of 0 at a price of $\underline{p}$, and a value of 1 at a price of r_H. Notice also that the value of $\underline{p}$ for which $G(p) = 0$ is the average of r_H and c_H.

Discounting. Now consider a change in the market institution that permits firms to offer discounts. As before, sellers choose list prices simultaneously, and these prices are observed by all traders. Next, buyers are selected, one by one, in a random order. Once selected, a buyer is given the chance to shop with all sellers in any order. When a buyer contacts a seller, the buyer may request a discount. The seller may either offer a discount or not, but any discount is not directly observed by other traders. The buyer responds by either purchasing or not. The difference between list prices and discounts in this institution is that list prices are selected simultaneously and are public information, but discount decisions are made sequentially and are only communicated to the buyer who is currently shopping. To summarize, list prices are simultaneous, nonselective, and public; discounts are sequential, selective, and private.

Now the buyers may be more actively involved. Without discounting, the buyer's best response to any set of posted prices is to shop first at the firm with the lowest price and only move to the high-price firm in the case of a stock out. With discounting, the possibility that the high-price firm discounts more aggressively may make other shopping strategies desirable. As will be seen presently, these alternative shopping strategies create additional equilibria for the stage game. We consider two equilibria. As will be seen, in one instance sellers compete on the basis of list prices, generating a mixed-strategy equilibrium that is similar in many respects to the equilibrium for the game without discounting. In the other instance, sellers fail to compete on the basis of list prices. The noncooperative equilibrium for this game is characterized by collusive prices.

An Equilibrium with Competition in List Prices. If the buyers first approach the seller posting the lowest list price, then there is mixed-strategy equilibrium very similar to that described above for the posted-offer market with no discounting. Given the buyers' shopping strategy, sellers would know that they would be approached only in the event that their price represented the lowest price available. For this reason, sellers would generally find discounting unprofitable, and they would compete on the basis of listed prices.

This equilibrium differs slightly from that described for the no-discounting case, because eight rather than six units will trade. The high-pricing seller knows that only the third buyer selected in the shopping sequence will approach him with a high-value unit. The first

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two buyers selected to shop will approach the high-pricing seller only after using their high-valued units to make purchases, without a discount, from the low-pricing seller. Consequently, the high-pricing seller could increase profits by offering a discount price of r_L to the first two buyers who approach him, and then offering no discount to the third buyer. Thus, as is intuitive, discounting can increase efficiency if sellers have enough demand information to price discriminate.

In this first equilibrium with discounting (denoted $d1$), the low-price seller sells all four units at list, and earns $L_{d1}(p) = 2(p - c_L) + 2(p - c_H)$, as was the case without discounting. The high-price seller, in contrast, sells two units at a discount in addition to the two units at list, and therefore earns $H_{d1}(p) = 2(p - c_L) + 2(r_L - c_H)$ in this case. If one inserts $L_{d1}(p)$ and $H_{d1}(p)$ into Eq. (1), the equilibrium mixed distribution is seen to be

$$G_{d1}(p) = (2p - r_H - r_L)/(p - r_L). \tag{3}$$

As for the case with no discounting, $G_{d1}(r_H) = 1$. With discounting, however, the value $\underline{p}$ that satisfies $G(p) = 0$ is slightly higher than in the case without discounting. With discounting, $\underline{p}$ becomes the average of r_H and r_L, rather than the average of r_H and c_H.

An Equilibrium without Competition in List Prices. Although buyers shop first with the low-price seller in the equilibrium just discussed, one might expect the reverse shopping pattern if buyers anticipate that the firm with the highest list price would feel more pressure to offer a discount. In this subsection we outline an equilibrium where the buyers shop first from the high-price firm, and switch only if that firm does not offer a satisfactory discount.

Suppose that buyers' equilibrium shopping strategies are characterized by some maximum reasonable list price $p^* \geq r_H$, above which buyers consider list prices to be unrealistic and uninformative. As long as the lowest list price is informative, that is, below p^*, then buyers' shopping strategies are to shop first from the high-price seller. Buyers will purchase all profitable units if this seller's discount price is less than or equal to a maximum acceptable transactions price p_M, defined to be the minimum of the lowest list price and the demand intercept r_H. Otherwise, the buyer switches and makes any profitable purchases from the other seller. If both list prices exceed p^*, or if list prices are equal, then buyers approach sellers randomly, request a discount, and purchase if the discounted price is no greater than their willingness to pay, r_H.

Given these shopping strategies, the high-price seller will discount when both list prices are above costs, and the optimal discount price is the minimum of r_H and the rival's list price. (This discount price is the

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highest price that will result in a sale.) Therefore, the seller with the lower *list* price faces the residual demand that remains after the other seller has sold all profitable units. The structure of this equilibrium is parallel to that described in the previous subsection. In both cases the seller facing the residual demand (in this case the low-price seller) offers a discount price of r_L for a single unit to each of the first two buyers who appear (because they have already purchased their two high-value units from the other seller), and offers no discount to the third buyer (who has not yet purchased the two high-value units).

The calculation of the profit functions for this second equilibrium with discounting, $H_{d2}(p)$ and $L_{d2}(p)$ is as follows. If the lowest of the two list prices is below p^*, the high-price seller discounts slightly below p_M (the minimum of the demand intercept and the lowest list price), and earns a profit of about $H_{d2}(p_M) = 2(p_M - c_L) + 2(p_M - c_H)$. The firm with the lower list price sells two units at his list price, which equals p_M for the case being considered, and sells two units at a discount price of r_L, thereby earning $L_{d2}(p_M) = 2(p_M - c_L) + 2(r_L - c_H)$. Because $H_{d2}(p_M) > L_{d2}(p_M)$ for $p_M > r_L$, it is better to have the higher of the two list prices when at least one list price is below p^*. It follows that each firm has a unilateral incentive to raise its list price at any common price on the range $[r_L, p^*)$. Thus, the incentive for a seller to lower the price to r_L is eliminated, which in turn rules out a mixed strategy equilibrium. Rather, there is a pure strategy equilibrium in this case: Each firm selects a list price at some arbitrary level above p^*, offers discounts to r_H, and on average earns a collusive profit of approximately $2(r_H - c_L) + (r_H - c_H)$.[1]

Dynamic Considerations. The analysis of stage-game equilibria allows some insight into the change in incentives created by discounting opportunities. Other considerations arise, however, when the game is repeated infinitely, or indefinitely (as would be the case in a normal market context). It is well known that in infinitely or indefinitely repeated games, collusive outcomes can be supported as trigger-price equilibria for a wide range of market structures; for example, a unilateral deviation from any cooperative price in one period could trigger a punishment of competitive pricing in subsequent periods (see e.g., Friedman, 1971). Collusive equilibria of this type can exist at virtually every supracompetitive price.

Simple intuition suggests that discounting opportunities would complicate the implementation and maintenance of such collusion. As mentioned in the introduction, private discount opportunities would

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[1] Unlike the case where at least one price is below p^*, sellers would generally refuse to sell a third unit to a buyer at a discount price of r_L, because this discount would preclude the possibility of selling the unit at the higher price of r_H to a subsequent buyer. However, if the last buyer selected approaches a seller who did not make sales to the first two buyers, then this seller would sell two units to the last buyer at r_H, and a third unit at a lower discount price of r_L.

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make it very difficult for sellers to identify defectors, or even to detect the incidence of a defection. An absence of expected sales could be caused by demand shocks or by buyers withholding purchases in a strategic manner, as well as by the private discounts of rivals. These effects are discussed by Stigler (1964), and Green and Porter (1984). But discounting does not necessarily eliminate collusive equilibria in an indefinitely repeated game. For example, if buyers act as passive price takers, sellers could naturally avoid the allocation uncertainty by taking turns charging prices of r_H and something slightly less than r_H. This price alternation removes the effect of random demand allocation, and a trigger-price equilibrium could be supported with sufficiently low (time) discount rates. But, of course, price discounting opportunities provide buyers with incentives *not* to act passively: Any buyer can refuse to purchase from either seller and thereby trigger a price war, because neither seller can distinguish such withholding from a loss of sales as due to discounts.

An Experiment to Evaluate the Effects of Discount Opportunities. The discussion of the preceding section demonstrates clearly that pricing predictions are sensitive to the shopping strategy choices of buyers, and to the marketing strategies of the sellers. Nevertheless, the (mixed strategy) equilibrium calculations are fairly involved, and it is probably not reasonable to suppose that sellers explicitly make such calculations, even under the best of conditions. A rather natural question pertains to the usefulness of the above predictions: If sellers do not explicitly make mixed strategy calculations, is there any force (such as the interaction of their choices) that drives sellers to outcomes that resemble these strategy choices? More generally, as a behavioral matter, when discounting opportunities are allowed are market outcomes sensitive to shopping and marketing strategy choices?

The difficulty of measuring the underlying incentives of buyers and sellers in naturally occurring markets, combined with the difficulty of directly monitoring buyer and seller actions, makes it very difficult to evaluate the behavioral validity of the above predictions with market data. However, some information about the reasonableness of the above predictions can be evaluated in terms of a laboratory experiment. This section describes the structure of such an experiment.

Prior to beginning, it is important to emphasize both what is not and is being done with this experiment. The experiment is not, and is not intended to be, a description of any naturally occurring market in particular, or of naturally occurring markets in general. Underlying circumstances characterizing natural markets are much more complex than those presented in the laboratory environment, and both buyers and sellers have much richer incentive considerations. The experiment can, however, be illustrative. It can shed some light on the plausibility

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of theoretical predictions. If the predictions fail under the ideal circumstances of the laboratory, there is little hope that they will work in more general conditions. Moreover, even if observed outcomes fail to match theoretic predictions with precision, the experiment can still demonstrate that in very simple market environments, shopping and marketing strategy choices are relevant to market outcomes.

Parameter choices. One problem with the market structure shown in Figure 1 is that buyers' profits would be zero if sellers were able to collude and enforce a price of r_H. Subjects may behave erratically in persistent zero-profit situations. In order to make prices near r_H viable, an inframarginal unit with a very high value, r_{max}, was given to each buyer, as shown by the step added to the upper left-hand part of the demand function in Figure 1. In addition, a parameter-disguising constant, denoted here by x, was varied across sessions, and the cost and value parameters were calculated as deviations from the competitive price of r_L:

$$\begin{aligned} r_{max} &= x+85 \text{ (demand intercept)},\\ r_H &= x+40 \text{ (collusive price)},\\ r_L &= x \text{ (C.E. price)},\\ c_H &= x-10,\\ c_L &= x-35, \end{aligned}$$

where all units are pennies. The additive constant was always high enough to ensure that $c_L > 0$. These parameters (for $x = 0$) are represented on the right-hand, vertical axis in Figure 1, which is labeled Experiment Parameters. The competitive price is an open circle, and the collusive price is a solid circle on this axis. For these values, the collusive price is still r_H, as can be verified by comparing the sellers' joint profit at prices of $x+40$ and $x+85$. Each seller's profit of 90 in the competitive equilibrium is sufficiently high so that the competitive equilibrium is also a viable outcome.[2]

Besides competition and collusion, it is natural to consider the single-period mixed equilibrium without discount opportunities, under the assumption of risk neutrality. For the value and cost parameters given above, the formula in (2) yields the equilibrium price distribution:

$$G(p) = [2p - 30]/[p + 10], \qquad \text{for } 15 < p < 40. \tag{4}$$

[2] The addition of the demand step at 85 does not alter the upper bound of the mixed distribution in any of the equilibria. Without discounting opportunities, each seller's equilibrium expected profit is $H(r_H)$ (=150) at any price in the interval (15,40) of randomization. If one seller were to choose the top price of 85, the first two buyers selected in the shopping sequence would buy two units from the other seller at a price between 15 and 40. The remaining buyer only has one unit with a reservation value of 85, so the deviation would be unprofitable. A deviation to any other price above 40 would also be unprofitable ex ante. For the mixed equilibrium with discounting opportunities, it can be shown similarly that the additional demand step does not affect the upper bound of the distribution determined by Eq. (3).

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The corresponding density function, denoted $g(p)$, is found by differentiation to be $g(p) = 50/[p + 10]^2$, which is decreasing in p. Most of the probability mass is located at the bottom of the distribution, and the median is 23.3¢.

Similarly, the formula in (3) yields the price distribution for the equilibrium in which discounting is possible and buyers shop first with the low-price seller:

$$G_{d1}(p) = (2p - 40)/p, \qquad \text{for } 20 < p < 40. \tag{5}$$

The median list price for this distribution is 26.6

A final parameter selection invloves specifying termination probabilities that support grim-trigger-strategy collusive outcomes. Our intention is to choose a common termination probability sufficiently low that trigger-strategy equilibria exist in both the baseline sessions and in sessions with discounting opportunities. Suppose that sellers are selecting the collusive price of 40, which yields profits for each of 200 cents on average. A small unilateral reduction would enable a seller to sell all four units and increase earnings from 200 to 250. This one-period gain is followed by reversion to noncooperative behavior (randomization) in subsequent periods, which reduces expected earnings to 150 in the no-discounting case, and to 170 in the discounting case. In the no-discounting equilibrium, the 50¢ increase in earnings in the deviation period is exactly balanced by the 50¢ reduction in earnings from the collusive price in subsequent periods if the probability of continuation is ½. (With a continuation probability of 0.5, the expected loss in future profits is $50[0.5 + (0.5)^2 + (0.5)^3 + \cdots] = 50$.) Similarly, in the equilibrium with discounting opportunities, the 50¢ increase in earnings from defection is balanced by the 30¢ reduction in earnings if the probability of continuation is ⅝ (= 0.625). Thus, in either design any continuation probability that exceeds 0.625 will allow the collusive outcome to be supported by grim trigger-price strategies. In each session, the continuation probability was 1 for the first 15 periods and 0.667 for each subsequent period.

Experiment Procedures. Experiment sessions were conducted in a laboratory of networked, visually isolated, personal computers at Virginia Commonwealth University. The participants were undergraduate business students who were recruited with a promise that they would receive a $3 participation fee in addition to all money that they earned in the session. Buyer and seller role assignments were made in a nonsystematic manner, and subjects did not learn their roles until after working through a common set of computerized instructions that familiarized them with screen displays and decision options of both buyers and sellers. The instructions for posted-offer markets are standard. A printed copy

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of the version used in this experiment appears in Davis and Holt (1993, pp. 223–232).

The ability of sellers to offer selective, privately observed discounts to particular buyers was implemented by altering a standard posted-offer institution, which will be described first. The baseline posted-offer (PO) sessions were conducted in the normal manner, with sellers selecting posted prices independently. Each seller would specify the maximum number of units that were offered at the price posted. Each seller was then prompted to confirm (key c) or rechoose (key r), and a warning appeared if the quantity limit was so high that one or more units could be sold at a loss. Prices, but not quantity limits, would then be displayed on all buyers' and sellers' screens below the seller ID numbers, S1 and S2. Then buyers would be chosen to shop in a random sequence. Once selected, a buyer could purchase from a seller by pressing the appropriate key. After confirming a purchase, profits would be calculated and displayed for the buyer and seller. No information about this contract would appear on any other subject's screen unless the seller ran out of units, in which case a NO UNITS message would replace the seller's ID on buyers', but not sellers', screens. Next, the buyer would be given the choice of purchasing another unit from the same seller, switching sellers, or stopping.

The list/discount (LD) procedures differ from the PO procedures in that a buyer who is shopping is given the option to request a discount, in addition to the other options of purchasing, switching sellers, or terminating. A discount request results in the appearance of a DISC REQ message under the buyer's ID number on the seller's screen. Then the seller would be prompted to make a price offer that could be less than or equal to, *but no greater than*, the original list price. After the counteroffer is confirmed, it would be communicated to the buyer, who then could either accept (purchase the unit) or reject (switch sellers and continue shopping, or stop shopping). The discount negotiation messages were private in the sense that they had no effect on others' screens, although a purchase could generate a NO UNITS message on buyers' screens.

Because no buyer would ever want to switch sellers more than once in the two-seller PO sessions, we imposed a single-switch shopping restriction explicitly in the LD sessions. This restriction had the benefit of reducing the number of minutes per market period so that trading times and hourly earnings were roughly comparable across institutions. Although this single-switch restriction has no effect on the theoretical analysis of equilibrium in the previous section, it introduces a type of shopping cost that could augment sellers' capacity to raise prices in other equilibria not considered.[3]

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[3] Shopping costs may be specified in a more continuous way. In subsequent work we have evaluated the performance of LD and PO markets when buyers pay a shopping cost each time they approach a different seller.

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We followed the common practice of only giving the subjects information concerning their own values or costs; they knew the numbers of buyers and sellers but were unaware of any symmetry relationships, et cetera. It follows that competitive, collusive, and Nash equilibria calculated previously must be viewed as benchmarks with which to evaluate data, because subjects would be unable to calculate these equilibria ex ante. The objective of this research is to analyze the effects of discount possibilities in imperfect informational environments, not to evaluate alternative noncooperative and competitive equilibria.

All subjects were informed that the laboratory session would last for at least 15 periods, with the throw of a die inducing a continuation probability of 2/3 in periods 16 and after. The same trading institution was used for all periods. Several sessions were also conducted with experienced subjects who had participated in at least one previous session with the same institution. No effort was made to match roles with previous roles, and no subject was exposed to both institutions.

Experiment Results

The results of six posted-offer sessions and six list/discount sessions are summarized in Tables 1 and 2. The 12 session identifiers are listed across the top of each table. Sessions are identified by institution (PO or LD), number in sequence (1–6) and experience level (*x* if participants had participated in a prior session). Half the sessions of each type used experienced subjects.[4] The analysis focuses primarily on price and efficiency performance across institutions. Prices are measured as penny deviations from the C.E. price. Table 1 presents average transaction price information for periods 6–15, which are the last 10 periods common to each session.

First consider price performance in the PO sessions, summarized on the left side of Table 1. With few exceptions, notably in PO3, prices are fairly stable, and are in the randomization range [15,40] throughout each session. Examination of the actual sequence of contract prices in a representative session provides a clearer perspective. The contract prices from PO1 are shown in Figure 2. Deviations from the C.E. price are plotted on the vertical axis, and trading periods are plotted along the horizontal axis. Horizontal lines at 15 and 40¢ denote the limits of the randomization range, with 40 also representing the

[4] We conducted one additional posted-offer session in the Figure 1 design that is not reported in this article. In this session, a confused buyer regularly made purchases from the high-price seller when a choice was available (this occurred in 7 of 15 possible periods.) This buyer also purchased units at a loss in two periods. These purchases generated very profitable additional sales for the high-priced seller and eliminated or severely damped incentives for sellers to cut prices. (Mean prices were 15 cents higher in this session than in any other PO session.) We felt that the buyer's behavior was sufficiently anomalous to warrant exclusion of the session. There was no obvious strategic benefit to the buyer for engaging in this costly behavior, and such behavior was very rare in the other posted-offer sessions.

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Table 1. Average Transactions Prices for Periods 6–15.

	Price—C.E. Price (in pennies)											
	Posted-Offer Sessions						List/Discount Sessions					
Pd.	PO1	PO2	PO3	PO4x	PO5x	PO6x	LD1	LD2	LD3	LD4x	LD5x	LD6x
6	12	22	12	23	25	19	52	05	50	16	23	23
7	17	26	12	31	21	32	47	11	32	15	45	31
8	13	22	14	27	20	27	67	13	39	12	36	28
9	24	23	13	19	17	21	50	06	53	19	36	30
10	22	22	11	25	22	26	62	11	24	13	26	33
11	19	21	21	20	21	32	60	10	32	14	51	23
12	17	19	35	15	19	31	48	16	38	11	40	16
13	21	17	48	27	16	29	48	12	44	09	46	17
14	21	17	41	22	17	26	51	07	21	14	38	14
15	16	10	19	27	20	23	36	14	46	09	49	13
Avg.* (6–15)	**18**	**20**	**20**	**23**	**20**	**27**	**49**	**11**	**37**	**13**	**38**	**22**

*Elements in this row are averages of *all* transaction prices in periods 6–15 (rather than averages of the mean prices per period).

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Table 2. **Average Efficiencies for Periods 6–15.**

Pd.	Efficiency (%)											
	Posted-Offer Sessions						List/Discount Sessions					
	PO1	PO2	PO3	PO4x	PO5x	PO6x	LD1	LD2	LD3	LD4x	LD5x	LD6x
6	96	96	96	96	83	96	65	96	52	98	89	96
7	96	96	96	83	96	96	66	89	69	98	69	96
8	96	96	96	96	96	96	60	98	74	96	96	69
9	96	96	96	83	96	96	22	96	57	87	87	87
10	96	96	83	96	96	83	65	98	69	96	89	96
11	96	96	60	96	96	96	60	100	60	96	74	87
12	96	96	74	96	96	96	61	89	61	96	74	89
13	96	96	65	96	96	96	96	96	69	98	87	96
14	96	96	74	96	96	96	69	96	61	96	96	96
15	96	96	96	96	96	96	98	98	74	96	78	96
Avg. (6–15)	**96**	**96**	**87**	**94**	**95**	**95**	**66**	**96**	**65**	**96**	**84**	**91**

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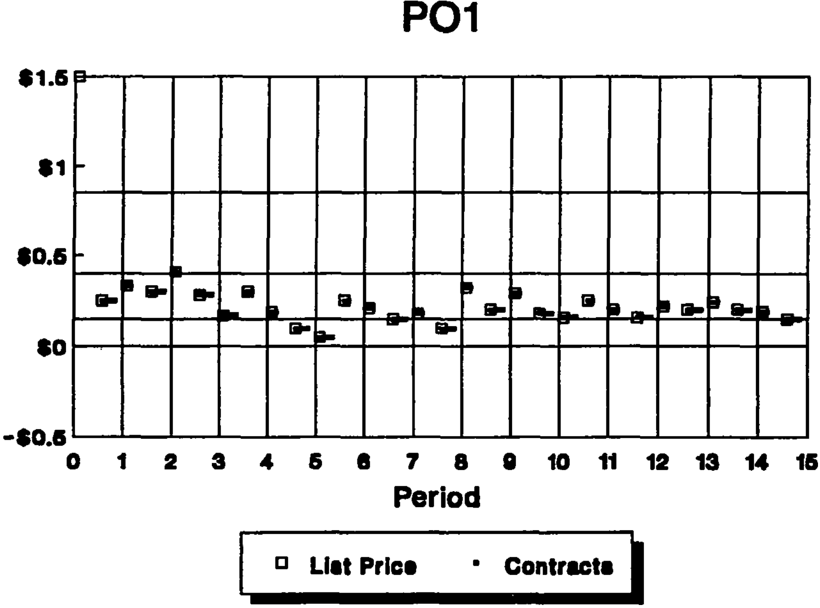

Figure 2 List and contract price deviations for session PO1.

collusive price. The third line, at 85¢, represents the demand intercept for buyers. Each vertical line indicates the end of a period. For each period, list and transaction price data are presented for S1 (to the left) and S2 (to the right). The hollow box represents the list price, and dots extending to the right of each box correspond to units sold.

Seller S1 in PO1 began the first period with no sales at a list price of 286¢ above the C.E. level. Although this price is off the vertical scale of Figure 2, it is represented by a hollow box at the top of the price scale. Seller S2's first-period price was down in the range of randomization, and four contracts were made, as indicated by the four dots extending to the right of S2's price box in period 1. Seller S1 lowered his list price in period 2, but only sold two units because S2 was again the low-price seller. Prices generally remained in the randomization range in subsequent periods, but tended toward the lower bound. Similar price patterns were observed in the other PO sessions, except that there was a price surge in periods 11 to 14 of PO3, when seller S2 attempted to stimulate tacit collusion. This attempt was unsuccessful, in the sense that prices reverted to earlier (unusually competitive) levels in periods 15–20. On balance, then prices appear to generally fall in the range of randomization. Nevertheless, it is incorrect to infer too much support for theoretic predictions from observed pricing patterns. Although most prices are in the predicted range, sell-

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ers generally did not price according to the theoretical mixed distribution. Using the nonparametric Kolmogorov-Smirnov test, the null hypothesis of randomization may be rejected at a 95% confidence level for periods 6–15 in five of the six sessions.

Efficiency information for the PO sessions is summarized in Table 2, which is formatted in the same way as Table 1. Efficiency is calculated as the percentage of the maximum possible surplus extracted in each trading period; for example, efficiency would be 100% at the competitive outcome (eight units traded at a price of r_L). With a few exceptions, particularly in PO3, 96% of the surplus was realized in periods 6–15 for each PO session. The 96% efficiency level is consistent with the sale of six units at prices in the range of randomization, underscoring the observation that although these markets did not converge to the competitive equilibrium, the loss in surplus from this deviation was small.

Consider now performance in the LD sessions. Examination of average transaction price data for the LD sessions in Table 1 reveals a striking increase in price variability. In two instances (LD2 and LD4x), prices were slightly below 20, the lower bound of the relevant randomization range. Prices were much higher in three of the remaining four instances (LD1, LD3, and LD5x).

One of these latter instances, LD1, is shown in Figure 3. This figure

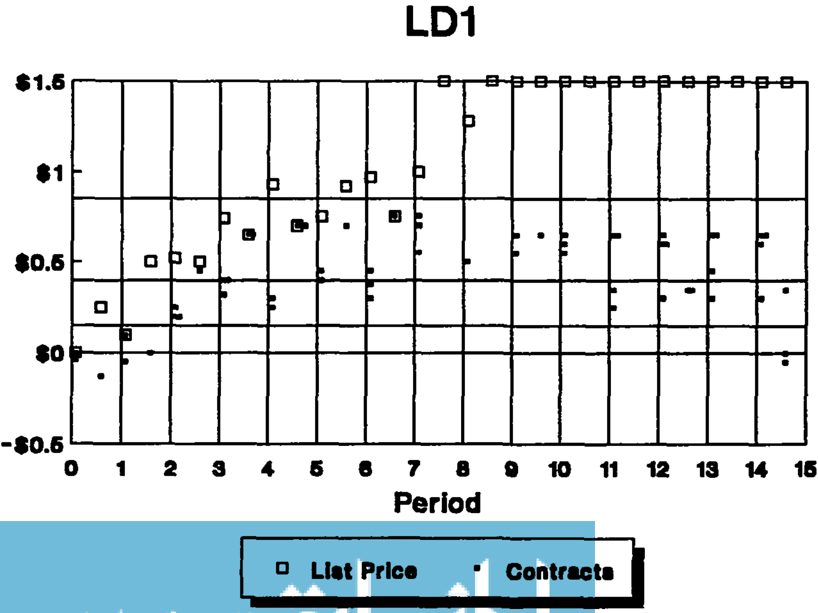

Figure 3 List and contract price deviations for session LD1.

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is similar to Figure 2, except that the dots representing transactions appear below the list-price box when discounts are given. List prices in LD1 began low but started to climb immediately. In period 4, both list prices were very high, but S1, with the higher list price, was visited first by a buyer who had previously obtained a 32¢ discount from this seller. Seller S1 again offered substantial discounts and sold all three units offered. The other buyers shopped with S2, who did not discount and managed to sell two units at a profit of 100 each. List prices continued to rise steadily (and off the scale in Figure 3) during the session until the final three periods, when S1 consistently listed a price 175 above the C.E., and S2 listed a series of prices between 200 and 220 above the C.E.

Throughout the first half of LD1, S2 refused to offer substantial discounts when he had the lower list price, but when S2 posted the higher list price, he tended to offer discounts that just beat S1's list price. The rise in list prices may be due to the fact that buyers tended to shop first with the seller with the high list price. This shopping pattern occurred on 22 of the 36 initial shops for which neither seller was out of stock in session LD1. These factors caused the earnings, particularly for S2, not to be adversely affected by having a higher list price, and S2 led the dramatic rise in list prices that followed period 8. Discounts increased in magnitude after list prices passed above the maximum buyer limit price. No units are sold at list in the last half of the session; discounts are substantial and varied.

The difference between list and transaction prices in session LD1 is representative of the relationship between list and transaction prices when discounting opportunities are allowed. This can be seen in Figure 4, which presents median list and transaction prices for periods 6–15 of the posted offer and list/discount sessions in respective upper and lower panels. In each panel, the horizontal lines at 15 and 40 represent the bounds of the relevant mixing distribution. Each session is denoted by a vertical line, which appears over the session identifier. Vertical lines are scaled in terms of deviations from the C.E. prediction, and on each line, the session's median list price is denoted by a box and the median transaction price is denoted by an *x*.

The small difference between list and transaction prices in the PO sessions are due to the tendency of the seller with the lower posted price to sell more units. From Figure 4 it is apparent that in list/discount sessions list prices are always much higher than transaction prices. In fact, median list prices exceed the demand intercept in many instances. In particular, note the wide disparity between median list and transaction prices session LD1, discussed above, and in sessions LD3 and LD5x. These two sessions were very similar to LD1, except that list prices rose above the buyers' demand intercept much earlier, but did not ultimately climb quite as high. Note also the higher trans-

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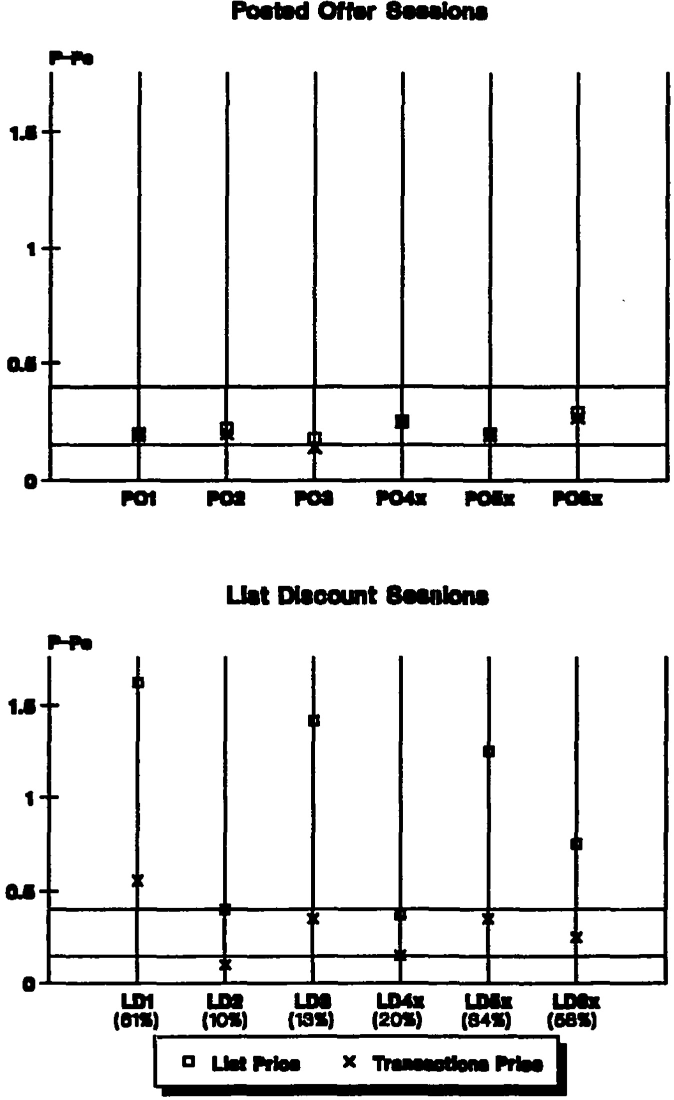

Figure 4 Median list and contract price deviations.

action prices in LD1, LD3, and LD5x, relative to those in the PO markets. Median transaction prices are near or above the collusive price in LD1, LD3, and LD5x, whereas median prices tend toward the lower part of the randomization range in the PO markets. Sessions LD1, LD3, and LD5x exhibit both high list prices and transactions prices

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near r_H, as predicted by the equilibrium in which buyers shop first from the seller with the highest list price.

Despite the persistent disparity between list and transaction prices in the LD sessions, further examination of Figure 4 suggests that the presence of selective discounting opportunities does not always make markets less competitive. Median transaction prices in sessions LD2 and LD4x are at or below the bottom of the randomization range. Figure 5 presents a more detailed history of price performance in one of these sessions, LD4x. In stark contrast to LD1, list prices not only remained well below the demand intercept price, but also below the collusive price for most of the session. Although this competition on the basis of list prices did not eliminate contract price heterogeneity in either LD2 or LD4x, it sharply constrained the sellers' capacity to price discriminate, and, as summarized in Table 1, mean price deviations LD2 and LD4x are at least 5¢ below the comparable figures for the PO sessions.

The efficiency data for periods 6–15 in Table 2 indicate that the price deviations also generate efficiency effects. The mean efficiencies of 66%, 65%, and 84% for sessions LD1, LD3, and LD5x, respectively, are much lower than comparable efficiencies in the PO trials, after controlling for experience. Thus, these three sessions make it clear

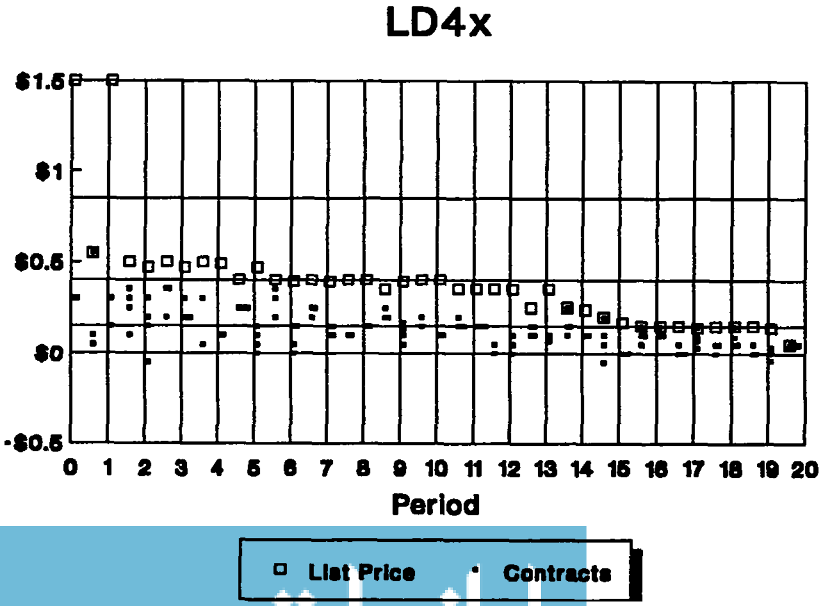

Figure 5 List and contract price deviations, session LD4x.

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that the presence of discounting can seriously hamper the competitive properties of experimental markets. Average efficiencies in LD2 and LD4x are comparable to those in the PO sessions.

Consider now the single remaining list/discount session, LD6x. As suggested by examination of Figure 4, this session is something of a hybrid of the other LD trials. As in LD1, LD3, and LD5x, each seller posted very high list prices in LD6x. Transaction prices, however, while above those for LD2 and LD4x, are not particularly high. The lower transaction prices are a consequence of the fairly generous rule of thumb for discounting adopted by one of the two sellers. This seller repeated a pattern of selling a first unit at 30, a second unit at 10, and all remaining units at 0. As suggested by the other sessions where list prices substantially exceed r_H, this seller could have earned considerably higher profits by discounting less freely.

Given the heterogeneity in performance in the LD markets, it is worth investigating the extent to which differences in buyer shopping behavior are associated with the list and contract price differences across sessions. Data relevant to this issue are summarized in the bottom panel of Figure 4, where the proportion of times that buyers approached the high-price seller first when a choice was available is listed in parentheses by each list/discount session identifier.[5]

Comparison of these ratios with median list and transactions prices in the list/discount sessions provides some rough support for the notion that shopping behavior influences pricing performance. In LD1, buyers chose frequently to shop first from the seller with the highest price, approaching the seller posting the highest price first 61% of the time (22 of the 36 instances where a choice was available). The high-price seller was also approached first quite often in LD5x (14 of 41 instances, or 34% of the time). Conversely, in the list/discount markets with small price deviations, buyers approached the high-price seller first a much smaller proportion of the time. The high-price seller was approached first about 10% of the time in LD2 (3 of 29 instances) and about 20% of the time in LD4x (9 of 45 possible instances) in LD4x.

Shopping behavior summarized at the bottom of Figure 4 is not an entirely consistent explanation of price differences across sessions, however. Substantial price deviations from the C.E. level were observed in LD3, for example, despite buyers' approaching the high-price seller first only 13% of the time (5 of 37 possible instances). Moreover, buyers approached the high-price seller first 58% of the time in LD6x, where transaction prices were the third lowest observed. These differences are not necessarily inconsistent with the theoretical analysis, as they may be due to (endogenous) differences across sessions in buyers' perceptions of the maximum informative list price, p^*.

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[5] These calculations include periods in which both list prices were above some critical level that might correspond to a maximum informative price p^*.

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Conclusion

The experimental data provide support for the qualitative predictions of the model. More importantly, both the laboratory data and the theoretical analysis suggest unambiguously that consumer shopping strategies and seller marketing strategies affect performance when discounting opportunities are added to the simple Bertrand model of price competition. The diversity of both predicted and observed outcomes in the list/discount environment suggest that it is probably unreasonable to ignore the possibility of selective, buyer-specific discounts in theoretical models of price competition. Moreover, the differences in behavior are attributable to essentially psychological and strategic factors of the type that are a primary focus in marketing. Buyers, for example, often both expect and receive large discounts from sellers posting high list prices. Sellers, in some circumstances, exploit this expectation, with the result of higher market transactions prices. It is also unreasonable to ignore the importance of such factors in the analysis of market performance.

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