Competitive Markets When Customers Anticipate Stockouts*

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Abstract

Retailers often worry about how shoppers will react when they find an empty shelf, but the anticipation of experiencing a stockout may also impact customer behavior. This in turn affects a retailer's optimal price and inventory choices. In this paper we explore how the feasibility of visiting a second seller in a differentiated product duopoly impacts market outcomes using a combination of theoretical modeling, experiments, and simulations. Behaviorally, when shoppers can only visit a single seller they overweigh the probability of being stocked out and avoid a seller they expect to be too crowded. A result of this is that a seller may sell more units by stocking a lower inventory. Subject sellers appear to anticipate this reaction when making price and inventory choices. However, when it is costless to visit a second seller, customers follow their dominant strategies. While subject sellers are observed to engage in excessive price competition, they do not under stock.

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"No one goes there anymore. It's too crowded." -Yogi Berra

Stockouts are potentially costly to retailers in that they represent missed sales opportunities. A shopper searching for a specific item may decide to purchase nothing, purchase a substitute good, or shop elsewhere if faced with an empty shelf.[1] Gruen et al. (2002) find that about half of stockouts result in the purchase of a substitute product. In this case the profitability of the seller may be positively or negatively affected depending on the relative profitability of the substitute item (see Kamakura and Russell 1989 for an empirical study suggesting people tend to trade up). Mahajan and van Ryzin (1999) provide a general survey of the literature on the impact of substitution on inventory management. Alternatively, the shopper may simply decide to abandon their shopping cart and visit a competitor instead. This decision depends on the price and selection offered by a rival store.[2] Matsa (2011) finds that grocery stores with more competition, especially from Walmart, are more likely to avoid shortfalls. Of course, retailers may prefer to run out of stock if they can offer rain checks (see Hess and Gerstner 1987) or as part of a bait and switch (see Wilke, et al. 1998a,b and Hess and Gerstner 1998). The impact of stockouts can extend beyond a single shopping trip. Anderson et al. (2006) show that current stockouts impact future purchases (see also Jing and Lewis 2011).

Recently, there have been several papers dealing with the optimal pricing of a good conditional on inventory levels (see Chen and Simichi-Levi 2010 for a survey).[3] One inventory situation that has been studied extensively is markdown pricing, where the seller has multiple periods over which it sells products and can mark remaining inventory down to induce sales. For example, Cachon and Swinney (2009) consider the inventory problem faced by a seller who anticipates dropping its price at some point during the season. Liu and van Ryzin (2008) consider stockout risk as a way to induce customers to buy earlier in the season (see also Aviv and Pazgal 2008, Allon and Bassamboo 2011, and Qi and van Ryzin 2011). Many of these optimal pricing papers focus on sellers who are insulated from competition or do not take shopper expectations into account.[4]

[1]Concern about how shoppers react to a stockout goes back to at least Walter and Grabner (1975). More recently, Honhon, et al. (2010) offers a dynamic programming solution to the optimal assortment problem when customers engage in stockout-based substitution.

[2]Balachander and Farquhar (1995) suggest that in some circumstances stockouts may have a positive effect on price competition.

[3]While much of the literature on inventory pricing is separate from the literature on substitutability between products, a recent paper by Transchel (2011) looks at the interplay between the two.

[4]Nagarajan and Rajagopalan (2009) look at a model where firms consider stockout-based substitution and competi-

If shopping is costly (in terms of time, gas, etc.), then customers may be captive to the retailer on that shopping trip. However, prior to visiting the seller, customers will choose where to shop based upon their perceived likelihood of finding the desired product in stock, which is a function of the quantity the retailer carries and the expected behavior of other shoppers, in addition to standard considerations such as price (travel costs, loyalty, etc.). This creates a variation of a "market entry game" played by shoppers who want to coordinate their actions as each shopper prefers to not experience an empty shelf, but wants to pursue the better deal if she will be successful. In the traditional market entry game, players privately decide if they wish to take a sure payoff or enter a pool where payoffs are decreasing in the total number of entrants. This game is modeled on firms deciding to enter a market where a monopolist would earn more than a duopolist who in turn would earn more than a triopolist and so on. The tension arises because there is a threshold number of entrants below which one wants to enter and above which one does not. Hence, in equilibrium only some firms should enter the market, but absent asymmetries there is a coordination problem as to who the entrants should be. Controlled laboratory experiments have consistently found that people quickly converge to equilibrium behavior in aggregate despite considerable individual heterogeneity (Rapoport 1995, Sundali, et al. 1995, Rapoport, et al. 1998, Ochs (1999) and Rapoport and Seale (2008). In fact, this pattern is so striking that Kahneman (1988) describes it as being "magic." However, as the coordination problem becomes more difficult due for example to overconfidence (Camerer and Lovallo 1999) or ambiguity (Brandts and Yao 2010) excess entry is often observed.

When sellers create a market entry game for shoppers, carrying a larger inventory may induce more shoppers to visit a store if the shoppers believe that they are more likely to find the item. Alternatively, a seller could end up with excess inventory on the shelf if customers falsely anticipate a stockout because they overestimate the probability that other shoppers will visit the seller. Everyone avoiding a store they believe will stockout is the retail variant of Yogi Berra's famous quip about no one going there any more because it is too crowded. The result is that having excess inventory could be a sign that too little or too much inventory was ordered. In this setting, price becomes a double edged sword for the retailer. Lowering the price makes the seller more attractive, which should increase the number of shoppers who visit; but, this makes a visit riskier and may have the unwanted effect of actually discouraging shoppers.

This paper examines how the potential for stockouts affects buyers' decisions regarding where to shop. We first construct a theoretical model with a three stage game in which two

tor inventory in a news vendor style duopoly.

sellers offer differentiated products with one being superior to the other (i.e. customers have a greater willingness to pay for the high quality seller's product). The high quality seller precommits to an inventory level, then both sellers post prices, and finally shoppers select which seller to visit and attempt to make purchases. If it is costless to visit the low quality seller after experiencing a stockout at the high quality seller, then all shoppers initially visit the seller offering the best deal. However, if it is prohibitively costly for shoppers to visit a second store, then the number of shoppers who visit each seller depends on the inventory level of the high quality seller and the buyer surplus (value minus price) at each location. The model we develop is in the vein of Deneckere and Peck (1995); however, in their model, sellers offer a homogenous product and shoppers are limited to visiting a single seller (see also Peters 1984). Despite the relative simplicity of the model, it is not possible to find an analytical solution for a symmetric equilibrium.[5] Therefore, we rely upon simulations and controlled laboratory experiments to understand this situation. Behaviorally, we find that shoppers are reluctant to visit the high quality seller as its inventory increases when stockouts are costly, a result that is consistent with probability weighting and yields behavior in line with Yogi Berra's statement.

1 Theoretical Model

Suppose there are two sellers offering differentiated products, one of high quality and one of low quality, to n shoppers. Define the two sellers as H and L, respectively. Assume each of the n shoppers desires only one unit. Further, assume all shoppers are identical and value the respective products at V_H and V_L, where $V_H > V_L$. Shoppers each independently make a decision regarding the product to purchase, and visit that seller initially. However, there is a possibility of a stockout at the high quality seller. If this occurs, a shopper can then choose to visit the low quality seller at some cost, which is captured by depreciating V_L by a factor of δ. For simplicity we consider the cases where $\delta = 0, 1$ capturing a prohibitive cost and no cost respectively. Further, it is assumed the low quality seller will have sufficient quantity to serve the market.

Given this structure, the type H seller will choose the inventory capacity $C \in [0, \overline{C}]$ they would like to carry, where it is assumed $\overline{C} < n$. High quality inventory has a per unit holding cost $K_C < V_H$, which is sunk once the product is procured. This cost can be thought of either

[5] There are also asymmetric equilibria such as exactly m shoppers out of n follow a pure strategy to visit a particular seller. There are other equilibria where some shoppers follow pure strategies of visiting the high quality seller or not while other shoppers do so probabilistically.

as a direct cost associated with the high quality product such as an actual price paid to the supplier or the cost of adjusting display space or an opportunity cost associated with foregone sales of some alternative product that could have been carried. For simplicity, both sellers are assumed to have no marginal cost. Once the high quality seller's inventory level is determined, it becomes common knowledge, both sellers privately and simultaneously set prices, and then shoppers make their purchasing decisions.[6]

Given this general setup, the stages of the game are as follows:

Stage 0: Nature chooses the depreciation factor, δ, and the number of shoppers, n.

Stage 1: The type H seller chooses its inventory level, C conditional on δ and n.

Stage 2: Each seller chooses P_i for $i = H, L$ conditional on C, δ, and n.

Stage 3: Shoppers make purchase decisions conditional on P_H, P_L, C, δ, and n.

Throughout this paper the business setting is taken to be a retail market where the high quality seller can be thought of as a small specialty shop with limited space and the low quality seller can be thought of as a general merchandiser that carries many similar substitute products. In this sense, the capacity choice can be taken as the current inventory of the specialty retailer or as its store size, which was a choice variable when the specialty shop opened. However, the model applies equally well to other business settings as well. For example, boutique restaurants often have limited seating or supplies of fresh quality ingredients while fast food chains have a seemingly limitless supply.

Analyzing the game using backward induction, we begin with the shopper behavior in stage 3. Given that we consider homogeneous shoppers who are not able to coordinate their actions, we focus on symmetric equilibria. It is assumed the n risk-neutral shoppers will choose the product that offers the greater expected surplus. As such, the decision whether to seek the high quality product depends upon their valuation of both products less the respective prices as well as the probability one can obtain the product from the type H seller if visited.

Each consumer's strategy space is as follows: $\{H, L\}$, $\{H, \varnothing\}$, $\{L, \varnothing\}$ and $\{\varnothing, \varnothing\}$ where the first element is the retailer they visit initially, and the second entry indicates whether they would visit L conditioned on having experienced a stockout at H initially. This strategy space also reflects the ability for a shopper to visit neither seller should both offer a negative surplus. Since pricing above value results in zero revenue to the seller, a type i seller will set $P_i \leq V_i$. In

[6]For a discussion of a similar problem where availability is unobserved see Dana (2001).

the event of a stockout at H, it is assumed that the C units are randomly allocated to the $m = C$ shoppers who visited H.[7]

Let λ denote the probability that an individual shopper visits the high quality seller initially. The surplus that a shopper obtains from a type i seller is given by $V_i - P_i$. If the low quality seller offers the greatest surplus, then all shoppers will visit L. That is, if $V_L - P_L \geq V_H - P_H$ then $\lambda^* = 0$.

If, on the other hand, $V_L - P_L < V_H - P_H$ then shoppers face a tension between the certain yet lower surplus from L and trying for the high surplus from H. Their decision depends on the chance of not being stocked out at H and the depreciating factor, δ. Let $p(\lambda \mid C, Q)$ represent the probability a shopper successfully makes a purchase at the high quality seller, if the $Q = n - 1$ other consumers go with probability λ to seller H who has C units. The expected payoff from the decision to visit H is given by the following.

$$p(\lambda \mid C, Q)(V_H - P_H) + [1 - p(\lambda \mid C, Q)] \max\{\delta V_L - P_L, 0\} \tag{1}$$

When $V_L - P_L < V_H - P_H$ the value δ takes in (1) will either make visiting H first a risky or riskless decision for the shopper. Thus there are two cases to consider.

1.1 Case 1: A Costless Stockout ($\delta = 1$)

1.1.1 Stage 3: Shoppers Make Purchasing Decisions

In this case a shopper who plays $\{H, L\}$ and experiences a stockout will receive the same payoff as a shopper who plays $\{L, \varnothing\}$. The condition to visit H becomes $p(\lambda \mid C, Q)(V_H - P_H) + [1 - p(\lambda \mid C, Q)](V_L - P_L) > V_L - P_L$, which holds so long as $V_L - P_L < V_H - P_H$. Thus in this case $\lambda^* = 1$.

1.1.2 Stage 2: Sellers Set Prices

In stage 2, H and L simultaneously choose their respective prices, P_H and P_L, given the high quality seller's capacity, C, and anticipating the reaction of shoppers in stage 3. When $\delta = 1$, L's profit function is discontinuous. If $V_H - P_H \geq V_L - P_L$, then n shoppers will visit H first. This leads to a stockout, and the $n - C$ shoppers who were unable to procure a unit at H will visit L. However, if L sets a price that yields $V_H - P_H < V_L - P_L$, then L captures all n

[7] This would be the case if arrival order was random and customers were served on a first-come first -served basis.

shoppers. Equation (2) defines L's profit function.

$$\Pi_L = \begin{cases} (n-C)P_L & \text{if } V_H - P_H \geq V_L - P_L \\ nP_L & \text{otherwise} \end{cases} \tag{2}$$

The first component in equation (2) shows L can set a relatively high price, but ensures it will receive relatively few shoppers when it does so. The second component in equation (2) shows L can serve the entire market, but must set a relatively low price to do so.

H's profit is also discontinuous. Should H offer a non-negative surplus and $V_H - P_H \geq V_L - P_L$ then H will sell all C units in its inventory. However, should it be that $V_H - P_H < \max\{V_L - P_L, 0\}$ then H sells nothing. This leads to the following profit function for H.

$$\Pi_H = \begin{cases} C(P_H - K_C) & \text{if } V_H - P_H \geq V_L - P_L, 0 \\ -CK_C & \text{otherwise} \end{cases} \tag{3}$$

From (3) it is clear that H wants to offer the greater surplus and thus prevent L from capturing the entire market. Additionally, L will also want to offer the greater surplus when the profit from doing so is greater than offering zero surplus and capturing the residual market, $n - C$. Given P_H, the profit to L for offering the greater surplus is greater than that from capturing the residual market when $n(V_L - (V_H - P_H)) > (n - C)V_L$ where $V_L - (V_H - P_H)$ is the price that equates the surplus from each firm. Rearranging in terms of P_H we find that L will prefer offering a greater surplus than H when $P_H > V_H - \frac{C}{n}V_L$, which is strictly positive given the assumptions that $V_H > V_L$ and $C < n$.

It is relatively straight-forward to demonstrate there is no pure strategy in pricing for either firm given these assumptions. For instance, if H sets a price of $P_H = V_H - \frac{C}{n}V_L$, then L's best response is $P_L^* = V_L$, an offer of zero surplus to the shopper. However, H's best response to L's zero surplus is to offer a surplus marginally greater than zero, thus raising its price to $P_H^* = V_H - \epsilon$. Yet now that $P_H - \epsilon > V_H - \frac{C}{n}V_L$, L has an incentive to offer the greater surplus to customers. This 'one-upping' in surplus offerings between firms demonstrates that the equilibrium pricing strategy will be mixed.

To define the mixed strategy over prices, let the surplus, s_i, offered by firm i, be drawn from the distribution F_i where $F_i(\underline{s_i}) = 0$ and $F_i(\overline{s_i}) = 1$. It is assumed that $F_i(\cdot)$ is differentiable everywhere. The probability density function will be denoted by f_i, which describes the probability with which a firm will choose a given surplus.

Given the mixed strategy of H and that $P_i = V_i - s_i$, the expected payout to L of offering a surplus of s is

$$F_H(s)(V_L - s)n + (1 - F_H(s))\,[n - C](V_L - s). \tag{4}$$

To generate indifference in L, we set (4) equal to the greatest profit L can unilaterally guarantee itself with a pure strategy. The 'security profit' that L can unilaterally guarantee itself is given by setting a price $P_L^* = V_L$ and therefore selling $n - C$ units. Thus, $\Pi_L^s = (n - C)V_L$. Setting (4) equal to Π_L^s and solving for $F_H(s)$ yields the mixed strategy

$$F_H(s) = \frac{n - C}{C}\frac{s}{V_L - s} \tag{5}$$

where $s \in \left[0, \frac{C}{n}V_L\right]$. The expected surplus for H, $E_H[s]$, can be calculated using the probability density function from this expression, which leads to

$$E_H[s] = \int_0^{\frac{C}{n}V_L} s f_H(s)ds = \left(1 - \frac{n - C}{C}\ln\left(\frac{n}{n - C}\right)\right)V_L \tag{6}$$

To express this result in terms of expected prices, we find that $E_H[P_H] = V_H - \left(1 - \frac{n-C}{C}\ln\left(\frac{n}{n-C}\right)\right)V_L$.

Similarly, the expected payoff to H for offering a surplus of s is

$$F_L(s)\,[(V_H - s)C - K_C C] + (1 - F_L(s))\,[-K_C C]. \tag{7}$$

The security profit for H is determined by the greatest price H can set and not get undercut by L, which was previously determined to be $P_H = V_H - \frac{C}{n}V_L$. Using this price to determine the security profit for H we find $\Pi_H^s = \left(V_H - \frac{C}{n}V_L - K_C\right)C$. Equating (7) to Π_H^s and solving for $F_L(s)$ we find

$$F_L(s) = \frac{V_H - \frac{C}{n}V_L}{V_H - s} \tag{8}$$

where $s \in \left[0, \frac{C}{n}V_L\right]$. Calculating L's expected surplus we find

$$E_L[s] = \int_0^{\frac{C}{n}V_L} s f_L(s)ds = \frac{C}{n}V_L - \left(V_H - \frac{C}{n}V_L\right)\ln\left(\frac{V_H}{V_H - \frac{C}{n}V_L}\right) \tag{9}$$

Thus, the expected price of L can be expressed as

$E_L[P_L] = \left(1 - \frac{C}{n}\right) V_L + \left(V_H - \frac{C}{n} V_L\right) \ln\left(\frac{V_H}{V_H - \frac{C}{n} V_L}\right).$

1.1.3 Stage 1: High Quality Seller Sets Inventory

Finally, in consideration of stage 1 behavior we seek the inventory C that maximizes H's expected profit. Given the mixed strategy in pricing, this is equivalent to maximizing its security profit, $\Pi_H^s = \left(V_H - \frac{C}{n} V_L - K_C\right) C$. Therefore $C^* = \min\{\text{argmax}\ \Pi_H^s, \overline{C}\}$. Table 1 summarizes the expected prices and profits to both sellers as H's stage 1 capacity decision, C, changes for a particular set of parameters. These parameter values are the same as those used in the laboratory experiments described in the next section. In particular we set $n = 6$, $\overline{C} = 5$, $K_C = 3$, $V_H = 15$, and $V_L = 9$. From Table 1 it is clear that with these parameters, $C^* = 4$.

Table 1: Expected Prices and Profits for $\delta = 1$

C	P_H^*	Π_H^*	P_L^*	Π_L^*
1	14.2	10.5	8.9	45
2	13.3	18	8.7	36
3	12.2	22.5	8.3	27
4	10.9	24	7.6	18
5	9.2	22.5	6.7	9

1.2 Case 2: A Prohibitively Costly Stockout ($\delta = 0$)

1.2.1 Stage 3: Shoppers Make Purchasing Decisions

In this case, the condition for a shopper to find it optimal to pursue $\{H, \varnothing\}$ rather than $\{L, \varnothing\}$ is $p(\lambda \mid C, Q)(V_H - P_H) > V_L - P_L$. Given the symmetry, if this shopper finds it optimal to visit H then the Q other shoppers will also find it optimal and the chance that any particular shopper is not stocked out is $\frac{C}{n}$. This implies that when $V_L - P_L < \frac{C}{n}(V_H - P_H)$, $\lambda^* = 1$.

When $p(\lambda \mid C, Q)(V_H - P_H) = V_L - P_L$ a shopper is indifferent between $\{H, \varnothing\}$ and $\{L, \varnothing\}$ and there is a mixed strategy equilibrium. To identify the mixed strategy equilibrium one must express p as a function of λ, C, and Q as in (10).

$$p(\lambda \mid C, Q) = \underbrace{\sum_{m=0}^{C-1} \binom{Q}{m} \lambda^m (1-\lambda)^{Q-m}}_{\substack{\Pr(m < C) \Rightarrow \\ \text{Receives Item at } H}} + \underbrace{\sum_{m=C}^{Q} \frac{C}{m+1} \binom{Q}{m} \lambda^m (1-\lambda)^{Q-m}}_{\substack{\Pr(m \geq C) \Rightarrow \\ \text{Randomly Receives Item at } H}} \tag{10}$$

The first summation in (10) represents the probability that H does not stock out. The second summation in (10) represents the probability that the shopper is able to buy the item from H when there is a stockout. The index variable m is the number of other shoppers who attempt to buy from H. When there is a stockout, given that $m + 1$ consumers are looking for the high quality item, the probability a consumer is randomly assigned an item is $\frac{C}{m+1}$. The mixed strategy equilibrium is determined by λ^*, which equalizes the expected payouts to consumers from visiting H or L first. After substituting the appropriate terms into (1), setting it equal to $V_L - P_L$ and rearranging, the equilibrium solution for λ^* is fully characterized by equation (11).

$$\sum_{m=0}^{C-1} \binom{Q}{m} (\lambda^*)^m (1-\lambda^*)^{Q-m} + \sum_{m=C}^{Q} \frac{C}{m+1} \binom{Q}{m} (\lambda^*)^m (1-\lambda^*)^{Q-m} = \frac{V_L - P_L}{V_H - P_H} \tag{11}$$

Unfortunately, λ^* does not have an analytical solution, but one can calculate the equilibrium value numerically for given parameter values.

1.2.2 Stage 2 & Stage 1: Sellers Set Prices, High Quality Seller Sets Inventory

In stage 2, H and L simultaneously choose their respective prices, P_H and P_L, given the high quality seller's capacity, C, and anticipating the reaction of shoppers in stage 3. In this case where $\delta = 0$, shoppers never visit L after experiencing a stockout at H. Since each shopper will visit H with probability $\lambda^*(P_H, P_L, n, C)$, the profit to H is given by

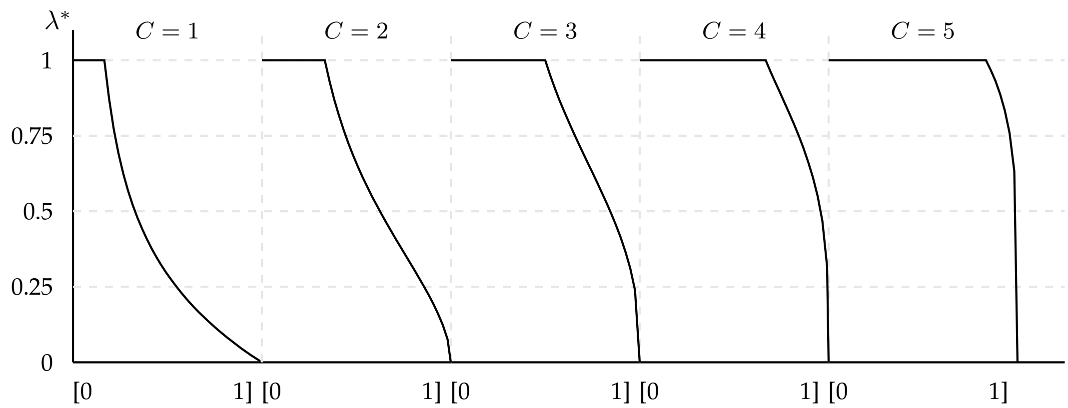
$$\Pi_H = P_H \min\{n\lambda^*, C\} - CK_C \tag{12}$$

and the profit to L is given by

$$\Pi_L = P_L \left(n - \min\{n\lambda^*, C\}\right). \tag{13}$$

If an analytical solution for λ^* could be obtained from (10) it would be straight forward to determine the optimal prices conditional on C and then the optimal C. Given that it is not, we rely upon numerical solutions to provide insight into stage 2 and stage 1 behavior in this case.

Figure 1: λ^* Across a Normalized Surplus from H for Different Capacities, C, $\delta = 0$



Surplus from L given a normalized surplus from H and capacity level C.

As in Table 1, the parameter values we use are the same as those that we use in the laboratory experiments discussed later in the paper. Figure 1 plots λ^* for different values of C. If H orders no inventory, its profit will be zero and $P_L^* = V_L$ making this case uninteresting and thus it is omitted. From the left hand side of (11) only the relative surplus at H and L are relevant to determining λ^*. Table 2 shows P_H^*, π_H^*, P_L^*, and π_L^* for different values of C. From the table it is clear that $C^* = 5$. Hence, with these parameter values the high quality seller should order less inventory when customers can costlessly visit a second seller.

Table 2: Prices and Profits for $\delta = 0$

C	P_H^*	Π_H^*	P_L^*	Π_L^*
1	10	7	6	28.4
2	8	10	4	14.3
3	7	12	3	6.7
4	6	12	1	2
5	6	15	1	0.5

2 Experimental Design

To further explore how buyers and sellers interact in a setting where customers can experience stockouts, we rely upon controlled laboratory experiments where the assumptions of the model can be exogenously imposed. In one experimental condition, the cost of visiting a second seller is prohibitively expensive (i.e. $\delta = 0$). In the second condition, it is costless for a shopper to visit a second seller in the event of stockout (i.e. $\delta = 1$).

The other model parameters were set as follows, consistent with the simulations presented in the previous section. V_H and V_L were set equal to 15 and 9, respectively. K_C, the inventory cost for each item the high quality seller orders in stage 1 was set equal to 3. Finally, the number of buyers in the market, n, was set to 6, and the maximum number of these buyers the high quality seller could serve, $\overline{C}$, was 5.

In an experimental session, the roles of shoppers (18 people), high quality sellers (3 people) and low quality sellers (3 people) were randomly assigned among a group of 24 subjects. Once a role was assigned, it was maintained throughout the 20 period experiment. A total of 4 sessions were conducted, resulting in a total of 240 markets. In two of the sessions, subjects first experienced the $\delta = 1$ condition for 10 periods and then the $\delta = 0$ condition for the last 10 periods. In the other two sessions, the condition order was reversed. Thus, the main treatment effect is measured using a within-subjects design.

Every period, three distinct markets were in concurrent operation. One high quality seller, one low quality seller and six shoppers were randomly assigned to each of the markets each period. The experimental feature of randomly shuffling subjects each period was common information and no identifying information was presented so participants did not know with whom they were interacting in any period. Subjects did not know if and when they might interact with that person again, as to parallel the one shot nature of the model. Each market period proceeded in three steps corresponding to those in the theoretical model described above, with all parameter values being public information. First, the high quality seller selected their inventory, which was then revealed to the low quality seller. The high and low quality sellers then privately and simultaneously set their prices. Finally, shoppers could observe both prices in their market as well as the inventory of the high quality seller. Shoppers privately and simultaneously determined which seller they wanted to visit, if any. Any shopper that experienced a stockout at the high quality seller was subsequently allowed to choose between visiting the low quality seller or not in the treatment where $\delta = 1$. Subjects only received feedback about their own market each period. The experiment was presented in a market context to the subjects, but the sellers were identified as "Firm A" and "Firm B" and no mention of high and low quality was made.

The experiments were run at the Behavioral Business Research Laboratory at the University of Arkansas. The participants were undergraduates at that institution and were drawn from a standing database of study volunteers, a majority of whom are in the business school. None of the subjects had previously participated in any related studies. In addition to the salient payment based upon earnings in the market, which averaged $13.57, subjects also received a $5 participation payment for the 90 minute session. Upon entering the laboratory, participants were seated at individual workstations separated by privacy dividers. Subjects then read the computerized instructions and answered a series of comprehension questions. The text of the directions and the questions are included in the appendix. Once everyone had finished the instructions, answered the comprehension questions, and had any remaining questions answered, the computerized experiment began. After the 10^{th} market period, a second set of directions and comprehension questions describing the second treatment was administered. Participants did not know the number of market periods nor did they know in advance that there would be a second condition. At the conclusion of the experiment, subjects were paid in private based upon their cumulative earnings, which were denoted in Experimental Dollars ($E). The conversion rate into $US was $E 20=$US 1 for sellers and $E 10=$US 1 for shoppers. Because high quality sellers could experience a loss due to the inventory cost, these sellers received an endowment of $E 200 that was added to their salient earnings. After receiving their payment, subjects were dismissed from the study.

3 Behavioral Results

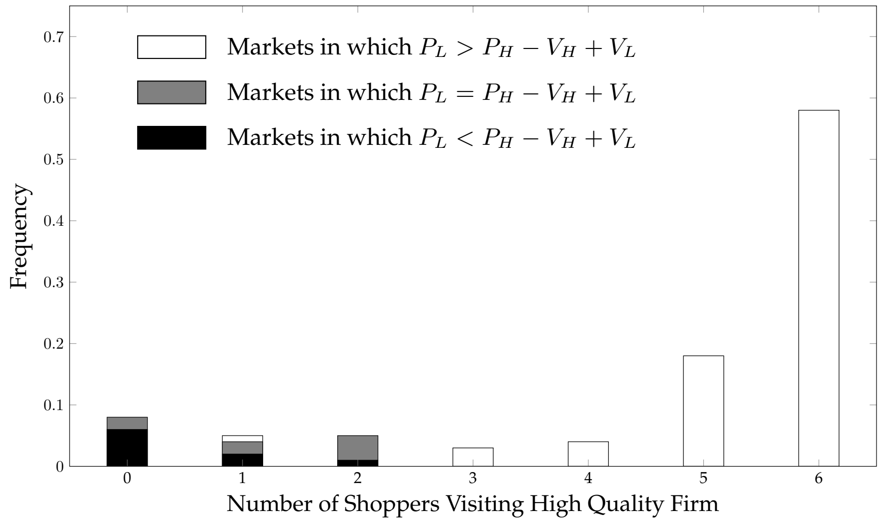
The results are presented separately for the case where $\delta = 1$ and $\delta = 0$. While the $\delta = 0$ case is the arguably more interesting given the tension that shoppers face, we begin our analysis with the $\delta = 1$ treatment because it provides a basis for evaluating subject behavior. As optimal behavior at a stage is contingent upon upon optimal reactions at subsequent stages, for each we consider the stages in reverse order.

3.1 Case 1: A Costless Stockout ($\delta = 1$)

When $\delta = 1$ a shopper should visit the seller offering the highest surplus since there is no loss from experiencing a stockout. Figure 2 reveals that subject shoppers are overwhelmingly following their dominant strategy. This result is important as it provides evidence that the subjects understand the decision environment.

Given that shoppers react optimally in stage 3, we step back to stage 2 to investigate the pricing game played by the sellers. Recall that sellers' profits are discontinuous when $\delta = 1$

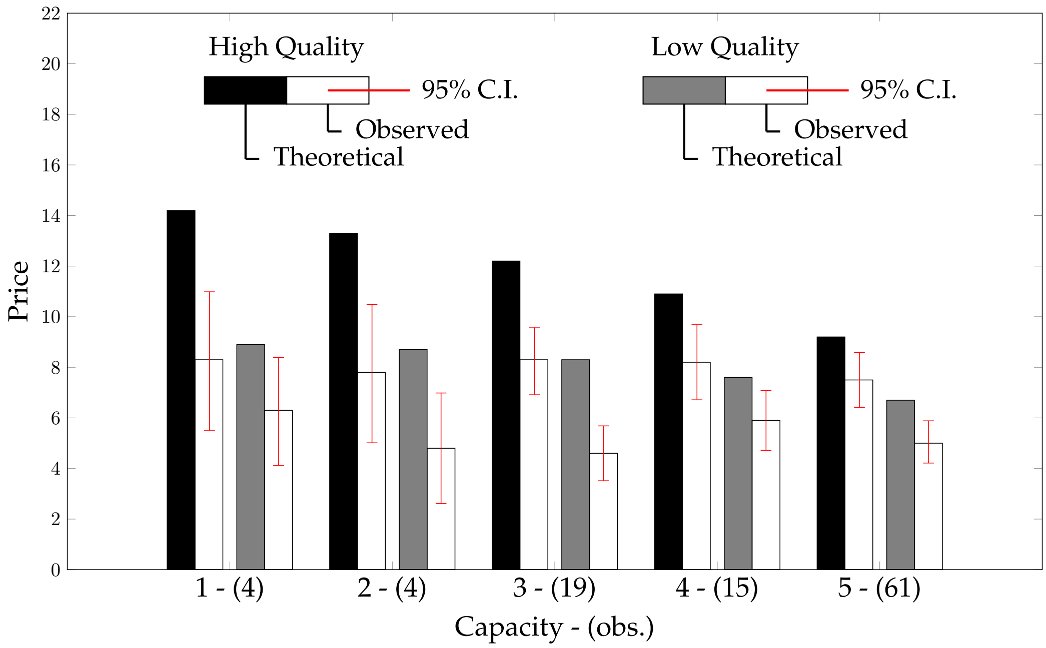
Figure 2: Shoppers Following Dominant Strategies for $\delta = 1$



and that there is a very strong incentive for each seller to offer a slightly greater surplus than its competitor. Figure 3 plots observed average prices for both high and low quality sellers along with the theoretical predictions for each seller type conditional on the inventory level of the high quality seller. The figure shows that prices are overly competitive (i.e. sellers charge prices that are too low). A similar pattern has been observed in other posted price duopoly experiments (see Brokesova et al. 2014, Aloysius et al. 2012, and Deck and Wilson 2006).

To statistically compare observed and predicted prices we rely upon regression results with standard errors clustered at the session level to account for the lack of independence of observations from a session. The regression results are presented in Table 3. The deviation in the observed price and the predicted price, conditional on the capacity set C, and firm type (H or L) is used for the dependent variable. Thus the dependent variable is Observed Price $-$ Predicted Price. Using this for the specification allows for a straight forward interpretation of the estimated parameters. The negative and statistically significant coefficient for the constant in this specification suggests that low quality firms are under-pricing. By adding the coefficient for the dummy variable indicating the high quality firm to this (Constant $+$ High Firm) we are able to test whether high quality firms are pricing as predicted, in which case Constant $+$ High Firm would not be statistically different from zero. However, the estimation suggests that high quality firms may be nominally under pricing by an even larger amount than low quality firms are, though this result is not statistically significant. In addition, we test whether low quality and high quality firms set prices as predicted at each capacity, which is estimated as

Figure 3: Comparison of Average Prices to Theoretical Prices for $\delta = 1$ Treatments



Constant + Capacity, and Constant + High Firm + Capacity + Capacity×High Firm, respectively. The estimated coefficients suggest the degree to which firms under price is mediated by larger capacities. The positive and statistically significant coefficient on $Capacity$ show that prices approach the predicted price as the capacity increases, though they never quite eliminate the deficit. Moreover, high quality firms under-price by a larger nominal amount on average for all capacity levels except at the largest capacity, a capacity of five.

Finally we look at the stage 1 inventory decision. The theoretical prediction is for $C^* = 4$. Despite the overly competitive prices in stage 2, the empirically optimal inventory choice remains 4. The average inventory for this case was 4.17, which, according to a two tailed t-test with clustered standard errors by subject, is not different from the theoretical prediction of 4 ($p < 0.71$).

3.2 Case 2: A Prohibitively Costly Stockout ($\delta = 0$)

As a shopper, one of two situations can arise. Either the low quality seller offers (weakly) more surplus in which case the shopper has a (weakly) dominant strategy or the high quality seller offer a greater surplus and the shopper faces a risk-return tradeoff. Figure 4 shows frequency that shoppers visit the high quality seller when they have a dominant strategy not

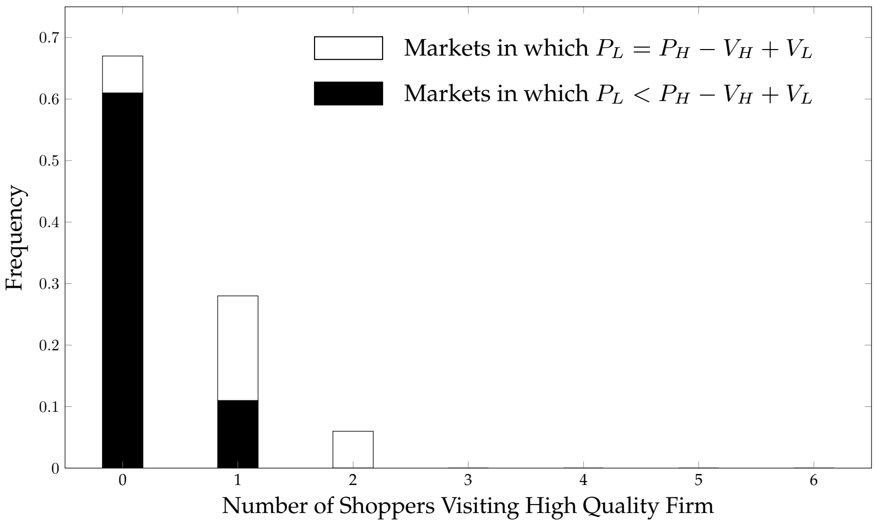
Table 3: Stage 2 Pricing for $\delta = 1$ Treatments

Dependent Variable: *Observed Price - Predicted Price*		
	Coefficient	Std. Error
Constant	-4.83***	0.75
High Firm (H)	-2.49	1.79
Capacity (C)	0.63***	0.22
Capacity × High Firm	0.49*	0.29
Observations	206	

Notes: Number of observations is 240. ***, **, and * indicate significance at the 1%, 5% and 10% level, respectively.

to do so. As in the case where $\delta = 1$ subject shoppers overwhelmingly follow their dominant strategy when they have one.

Figure 4: Shoppers Following Dominant Strategies for $\delta = 0$



Panel (a) of Figure 5 shows the predicted and observed number of shoppers who visit the high quality seller when it offers the greater surplus. The x-axis in this figure is the relative benefit to a shopper of purchasing from the high quality seller defined as $\frac{(V_H - P_H) - (V_L - P_L)}{V_H - P_H} = 1 - \frac{V_L - P_L}{V_H - P_H}$. Notice that the axis runs from 0 to 1 for each possible positive value of C. If the expected payoff from visiting the high quality seller even if the other $n-1$ shoppers do too is sufficiently high then $\lambda^* = 1$ and a shopper should visit the high quality seller with certainty. Formally, $\lambda^* = 1$ when $\frac{C}{n}(V_H - P_H) + \frac{n-C}{n}(0) > V_L - P_L$, which can be rewritten as $\frac{V_L - P_L}{V_H - P_H} < \frac{C}{n}$ or $1 - \frac{V_L - P_L}{V_H - P_H} > 1 - \frac{C}{n}$. The situation in which $\lambda^* = 1$ is shown in Figure 5 as the horizontal segment for the predicted number of shoppers visiting the high quality seller. The observed number of shoppers when the relative benefit is in this region are shown with white markers. When the relative surplus at the high quality seller is positive, but not sufficiently high to yield $\lambda^* = 1$, then shoppers should play a mixed strategy. The expected number of shoppers that should visit the high quality seller in this region is given by the nonlinear segments in Panel (a) of Figure 5. Observed behavior in this region is shown with black markers.

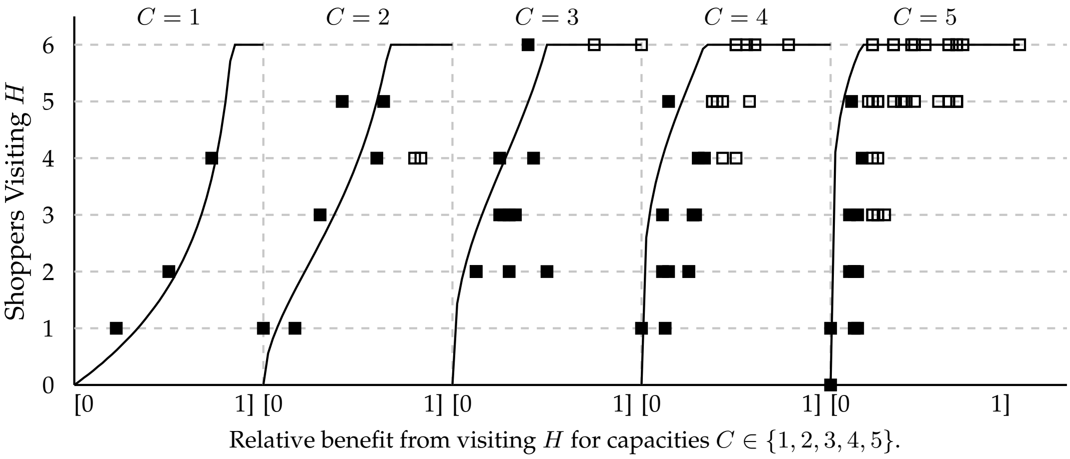
Several patterns emerge from Panel (a) of Figure 5. First, shoppers are more likely to visit the high quality seller, the greater the relative surplus offered by the high quality seller as evidenced by the markers trending up in each block. That is, conditional on C observed and predicted behavior are moving in the same direction. However, predicted behavior does not fit observed behavior very well once $C \geq 3$. In fact, the gap between the predicted number of shoppers and the observed number of shoppers is increasing in C. Second, shoppers are reticent about visiting the high quality seller even when the relative benefit is large enough that everyone should - white markers often short of 6. Further, when shoppers should be mixing, the observed number of shoppers visiting the high quality seller is decreasing in inventory for a given relative surplus level - there is a downward trend in the black markers across blocks. This is highlighted in the probit estimate summarized in Table 4. As in the regression analysis from Table 3, we only provide statistical tests for inventory levels of $C = 4$ and 5 because these account for sixty five percent of the observations.

Table 4: Stage 3 Shopper Decision for $\delta = 0$

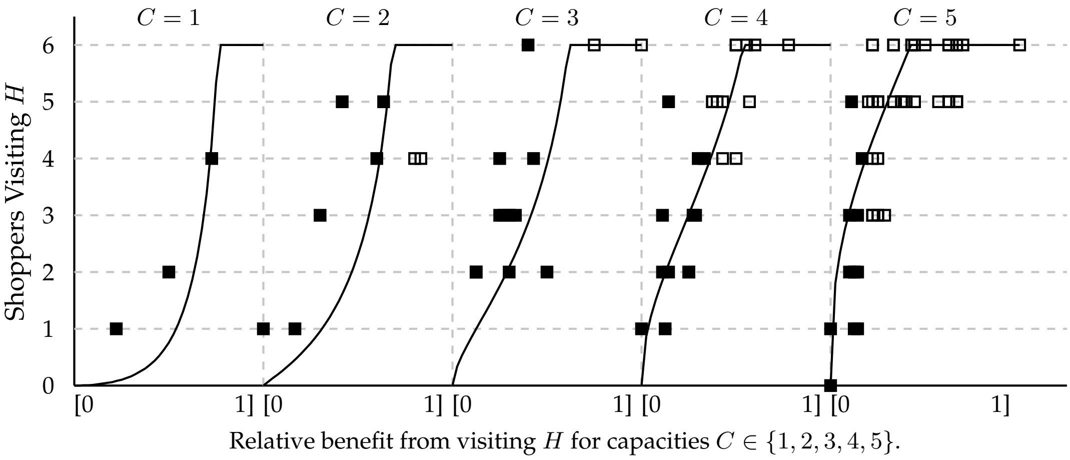
Dependent Variable: *Shopper Decision* (1=Visit H)				
	Coefficient	Std. Error	Marginal Effect	Std. Error
Constant	1.94*	1.02		
Capacity (C)	-0.44**	0.21	-0.14**	0.06
Relative Surplus	-4.47***	1.14	-1.53***	0.37
Capacity $\times$ Relative Surplus	1.18***	0.26	0.40***	0.08

Notes: Number of observations is 396. ***, **, and * indicate significance at the 1%, 5% and 10% level, respectively.

Figure 5: Shoppers: Expected Payoff Maximizers Vs. Probability Weighting



(a) Number of shoppers who visit H, assuming shoppers are expected payoff maximizers. The surplus between high and low quality firms are relative to the surplus at the high quality firm.



(b) Number of shoppers who visit H, assuming shoppers are probability weighting with $\gamma = 0.546$. The surplus between high and low quality firms are relative to the surplus at the high quality firm.

We consider two possible behavioral explanations for the shopper behavior we observe in this treatment: risk aversion and probability weighting. For risk aversion we assume that shopper attitudes can be captured by the one parameter constant relative risk aversion model where $u(x) = \frac{x^{1-r}}{1-r}$, perhaps the most commonly used specification for risk aversion. For probability weighting, we also rely on a common single parameter model; specifically $w(p) = \frac{p^\gamma}{[p^\gamma + (1-p)^\gamma]^{\frac{1}{\gamma}}}$. With p given by (10), λ^* is determined by equating $w(p)u(V_H - P_H)$ and $u(V_L - P_L)$ which can be rewritten as $\frac{V_L - P_L}{V_H - P_H} = [w(p)]^{\frac{1}{1-r}}$.[8]

To find the values of γ and r that best fit our data, we conducted a grid search over possible parameter values and selected the ones that generated the least sum of squared errors. The result was $r = 0$, corresponding to risk neutrality and $\gamma = 0.546$. This value of γ is similar to previous estimates from Tversky and Kahneman (1992), Camerer and Ho (1994), Wu and Gonzalez (1996), and Berns et al. (2008) which range from 0.56 to 0.71. Panel (b) of Figure 5 plots the observed behavior against the behavioral model with $r = 0$ and $\gamma = 0.546$. The similarity in the predicted and observed behavior once probability weighting is allowed is quite striking. To provide statistical support for the modified model, we conducted 10,000 simulations of the decisions shown in panel (b) of Figure 5 assuming each person makes his or her choices randomly.[9] From the simulation we calculated the sum of squared deviations between the simulated data and the prediction of the modified model. From this we could construct a distribution for sum of squared deviations under the null hypotheses of random behavior. The sum of squared deviations from the experimental data was smaller than 100% of the simulations leading us to reject the null hypothesis of random behavior in favor of the probability weighting model (p-value < 0.001).

Probability weighting leads subjects to exaggerate the chance that they will experience a stockout when lots of other shoppers are expected to visit the high quality as would occur if the high quality seller has a large inventory or sets a low price. This overblown concern leads subjects to avoid crowds, a manifestation of Yogi Berra's statement.

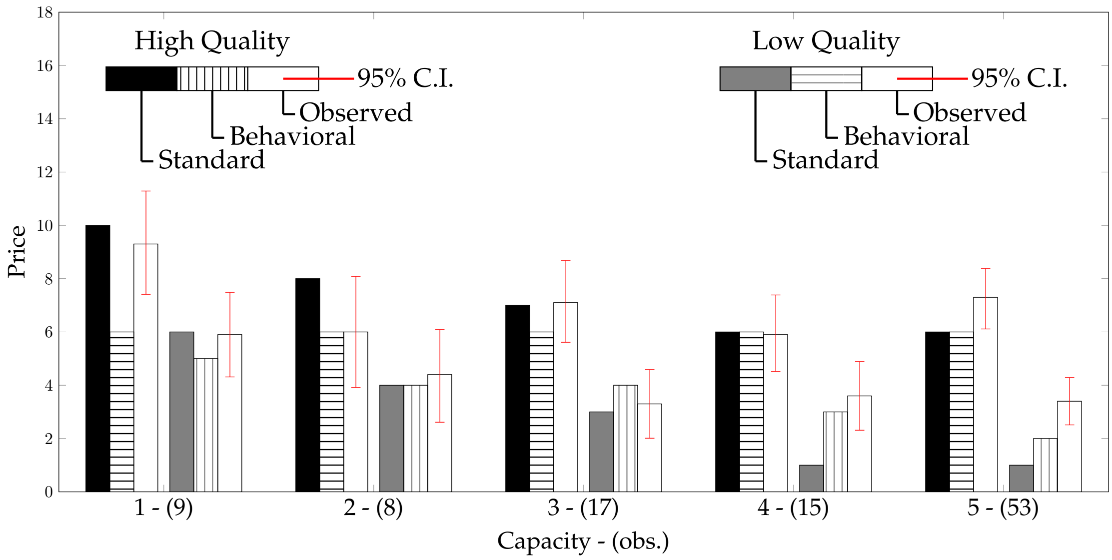
In considering the pricing decisions of sellers at stage 2, we consider both the theoretical predictions based on shoppers behaving optimally and an empirical optimal strategy that takes the probability weighting of the shoppers into account. The white bars in Figure 6 show the average observed prices by high and low quality sellers. Black bars represent the average theoretically optimal average price under the *standard* model while the striped bars represent optimal prices under the *behavioral* model. The results in Figure 6 show moderately compelling evidence that sellers are adjusting their prices in a way that reflects probability weighting by shoppers. In particular, high quality firms set prices that are remarkably close to the point predictions of the probability weighting model for capacities of two, three and four. Moreover, the probability weighting model implies that low quality firms will find it optimal to reduce their price at a

[8] By assumption, u(0)=0.

[9] For robustness, two variations of random behavior were simulated. For one simulation, random behavior was simulated as a coin flip - half of the time visiting H, the other visiting L. In another simulation, random behavior was simulated according to capacity divided by the number of customers (e.g. if capacity was $C = 2$, then shoppers would visit H $\frac{2}{6}$ of the time). The conclusions are robust to the specification.

slower rate as capacity increases, relative to the standard model and this is the pattern that we observe.

Figure 6: Comparison of Average Prices to Rational and Behavioral Prices for $\delta = 0$ Treatments



Finally, in stage 1 the average observed inventory when $\delta = 0$ was 3.86. Under both the *standard* model and the *behavioral* model $C^* = 5$. Hence, when $\delta = 0$ a one-tailed t-test confirms the high quality seller is under stocking inventory ($p < 0.001$).

4 Conclusions

Inventory levels are a major decision variable for many firms. Typically, a firm running out of inventory is viewed as suboptimal because of missed sales opportunities. Having excess product on the shelf is taken as evidence that too much inventory was ordered. However, an important aspect of determining inventory levels lies with understating how that choice will impact market prices and the reaction of shoppers. These effects hinge not only on the consumer surplus sellers offer, but also on customer expectations of experiencing a stock out and the options that are available to customers when they do experience a stock out. Offering a better price and having a larger inventory may attract more shoppers, but they could have the opposite effect if customers are worried that the store will be too crowded and a stock out is likely.

When visiting a second seller after experiencing a stock out is costless, then shoppers should visit the seller offering the best deal, which is what we observe in the laboratory. In this setting we find the typical pattern that subject sellers are overly competitive, but do make optimal inventory decisions. However, when visiting a second seller is prohibitively costly we find that subject shoppers fear being stocked out and avoid sellers with large inventory more than they should. Further, we find evidence that this behavior is driven by probability weighting rather than risk aversion. That is, having a larger inventory may exacerbate rather alleviate shopper concerns regarding product availability. We find some evidence that subject sellers anticipate this reaction by shoppers in terms of price setting, but ultimately respond by cutting inventory more than they should.

Our results indicate that sellers need to account for behavioral responses of shoppers when making pricing and inventory decisions. Of course, one always needs to be concerned when extrapolating from one setting, such as the laboratory, to another setting, such as a specific naturally occurring market. For example, one issue that is often raised with laboratory experiments is the sophistication of the subjects. This is typically emphasized more on the seller side of the market than the buyer side since college students have years of experience looking at prices in the real world. While it is natural to think of sellers as large sophisticated organizations, 79.9 percent of business in the United States in 2014 had no employees according to the Small Business Administration.[10] Further, subject sellers in the laboratory have several advantages over their counterparts in the real world, namely perfect information about market conditions (parameters) and the ability to operate in a static framework.

Ultimately, we believe that further theoretical, empirical, and behavioral research is needed to understand how firms' inventory decisions and customers' expectations affect market outcomes in competitive settings.

[10]See https://www.sba.gov/sites/default/files/FAQ_March_2014_0.pdf.

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5 Appendix

5.1 Subject Directions and Comprehension Questions

Items in italics were not observed by the subjects. Items in brackets were role specific.

Subject Instructions

Instructions, Page 1

In this experiment some people will be in the role of a firm and others will be in the role of a buyer. Buyers and firms will have the opportunity to buy and sell fictitious products with each other via their computers in a market. Firms earn money when they sell these items for more than their costs and buyers earn money when they purchase items at prices below their values. At the end of the experiment you will be paid based upon your earnings. Since you are paid based upon your decisions, it is important that you understand the directions completely. If you have any questions, please raise your hand and someone will come to your desk.

Instructions, Page 2 for Sellers

This experiment will last for several market periods. In each period you will be randomly matched with other people in the experiment.

In each market there are 2 Firms, A and B, and 6 buyers.

You will be Firm [A/B] and will retain the same role throughout the experiment. However, it is very important to understand how all the roles work.

All of the buyers value Firm A's product at $15.
All of the buyers value Firm B's product at $9.
A buyer can only purchase one unit in each period.

Each market period has three phases.

Phase 1: Firm A makes an inventory decision.
Phase 2: Firms A and B set their prices.
Phase 3: Buyers decide what to buy.

We will next describe each phase in detail.

Instructions, Page 2 for Buyers

This experiment will last for several market periods. In each period you will be randomly matched with other people in the experiment.

In each market there are 2 Firms, A and B, and 6 buyers.

You will be a buyer and will retain the same role throughout the experiment. However, it is very important to understand how all the roles work.

All of the buyers value Firm A's product at $15.
All of the buyers value Firm B's product at $9.
A buyer can only purchase one unit in each period.

Each market period has three phases.

> Phase 1: Firm A makes an inventory decision.
> Phase 2: Firms A and B set their prices.
> Phase 3: Buyers decide what to buy.

We will next describe each phase in detail.

Instructions, Page 3

During Phase 1, Firm A will decide what quantity to order. This is the maximum amount that Firm A can sell in the market. Firm A can order between 0 and 5 units. Notice that this means Firm A cannot order enough units to serve all 6 buyers. Each unit Firm A orders costs Firm A $9 regardless of whether or not Firm A ultimately sells the unit or not. Units cannot be carried forward from one market period to the next.

Instructions, Page 4

During Phase 2, Firm B will learn how many units Firm A ordered. Firm B always has 6 units of available to sell each period and does not incur any cost for these units. Firm A and Firm B will both set their price for the current period. Both firms will set their prices in private, but both firms will learn of the other firm's price after both prices are set.

Instructions, Page 5 for $\delta = 0$ Treatment

During Phase 3, each buyer chooses to go to Firm A, Firm B, or neither.

Any buyer who goes to Firm B will buy a unit from Firm B at Firm B's price. These buyers' earnings will be $9 minus Firm B's price. Recall that Firm B always has enough units to serve all buyers.

If the total number of buyers who go to Firm A is less than or equal to the number of units that Firm A ordered, each of the buyers who goes to Firm A will buy a unit from Firm A at Firm A's price. These buyers' earnings will be $15 minus Firm A's price.

If the total number of buyers who go to Firm A is greater than the number of units that Firm A ordered, then Firm A experiences a stock out and the computer will randomly pick which buyers actually get to purchase Firm A's units.

The buyers who get to buy from Firm A will earn $15 minus Firm A's price.

The buyers who are not randomly selected to buy units from Firm A will earn $0.

Any buyer who chooses to go to neither firm will not buy a unit and will earn $0 for the period.

Instructions, Page 5 for $\delta = 1$ Treatment

During Phase 3, each buyer chooses to go to Firm A, Firm B, or neither.

Any buyer who goes to Firm B will buy a unit from Firm B at Firm B's price. These buyers' earnings will be $9 minus Firm B's price. Recall that Firm B always has enough units to serve all buyers.

If the total number of buyers who go to Firm A is less than or equal to the number of units that Firm A ordered, each of the buyers who goes to Firm A will buy a unit from Firm A at Firm A's price. These buyers' earnings will be $15 minus Firm A's price.

If the total number of buyers who go to Firm A is greater than the number of units that Firm A ordered, then Firm A experiences a stock out and the computer will randomly pick which buyers actually get to purchase Firm A's units. The buyers who get to buy from Firm A will earn \$15 minus Firm A's price.

The buyers who are not randomly selected to buy units from Firm A will then have the option to either go to Firm B or not. If these buyers choose to go to Firm B they will earn \$10 minus Firm B's price. If these buyers choose not to go to Firm B they will earn \$0.

Any buyer who chooses to go to neither firm will not buy a unit and will earn \$0 for the period.

Instructions, Page 6 for Sellers

Firm A's earnings for the period equal (Firm A's price $\times$ number of units Firm A sold) - (\$9 $\times$ number of units Firm A ordered).

Firm B's earnings for the period equal (Firm B's price $\times$ number of units Firm B sold).

After each period, a table on the right-hand side of your screen will be updated with information about how many units Firm A ordered, the prices of both firms, and the number of units that each firm sold. Buyers' summary tables also record their own choice of which firm to visit. Keep in mind that all of the other people in your market are determined randomly each period.

At the end of the experiment, the amount you earned will be divided by 20 to determine your payment in US dollars. If you have any questions, please raise your hand. Remember that you are paid based upon your decisions so it is important that you understand the directions completely.

Instructions, Page 6 for Buyers

Firm A's earnings for the period equal (Firm A's price $\times$ number of units Firm A sold) - (\$9 $\times$ number of units Firm A ordered).

Firm B's earnings for the period equal (Firm B's price $\times$ number of units Firm B sold).

After each period, a table on the right-hand side of your screen will be updated with information about how many units Firm A ordered, the prices of both firms, and the number of units that each firm sold. Buyers' summary tables also record their own choice of which firm to visit. Keep in mind that all of the other people in your market are determined randomly each period.

At the end of the experiment, the amount you earned will be divided by 10 to determine your payment in US dollars. If you have any questions, please raise your hand. Remember that you are paid based upon your decisions so it is important that you understand the directions completely.

Comprehension Questions

Subjects were presented with a scenario and had to answer a series of questions on the computer. The feedback depended on the answers given. In the scenario, X, Y and Z are all discrete uniform random variables in an attempt not to bias subsequent behavior.

X was equally likely to be 2, 3, 4 or 5.
Y was equally likely to be 9, 10, 11, 12, 13, 14 or 15.
Z was equally likely to be 1, 2, 3, 4, 5, 6, 7, 8 or 9.

The version below is for the treatment when $\delta = 0$. The version for the treatment when $\delta = 1$ is omitted.

Comprehension Questions, Page 1

Let's work through a few questions to make sure you understand the way the experiment will work. The following questions will not impact your payoff in any way. Instead, these questions are designed to ensure that everyone understands exactly how this experiment is structured and exactly how your payment will be calculated when the study is over. Please feel free to raise your hand at any point if you have any questions.

Comprehension Questions, Page 2

Suppose Firm A orders <X> unit(s) and sets a price of $<Y> while Firm B sets a price of $<Z>.

If <X - 1> buyer(s) visit Firm A,

...how many units will Firm A sell?

Comprehension Questions, Page 3a (screen shown when subject's answer was correct)

Suppose Firm A orders <X> unit(s) and sets a price of $<Y> while Firm B sets a price of $<Z>.

If <X-1> buyer(s) visit Firm A,

...how many units will Firm A sell? You said: [subject's input]

That is correct.

Comprehension Questions, Page 3b (screen shown when subject's answer was incorrect)

Suppose Firm A orders <X> unit(s) and sets a price of $<Y> while Firm B sets a price of $<Z>.

If <X-1> buyer(s) visit Firm A,

...how many units will Firm A sell? You said: [subject's input]

That is incorrect. The correct answer is <X-1>. If Firm A orders at least as many units as it has customers visit, then it will always sell to whomever visits. Since Firm A ordered <X> unit(s) and only <X-1> buyers visited, Firm A would have been able to sell to each customer.

Comprehension Questions, Page 4

Suppose Firm A orders <X> unit(s) and sets a price of $<Y> while Firm B sets a price of $<Z>.

If <X-1> buyer(s) visit Firm A,

...how many units will Firm A sell? You said: [subject's input]

...The correct answer was <X-1>.

...how much profit will Firm A earn? Recall that profit is equal to (Firm A's price × number of units Firm A sold) - ($9 × number of units Firm A ordered).

Comprehension Questions, Page 5a (screen shown when subject's answer was correct)

Suppose Firm A orders <X> unit(s) and sets a price of $<Y> while Firm B sets a price of $<Z>.

If <X-1> buyer(s) visit Firm A,

...how many units will Firm A sell? You said: [subject's input]

...The correct answer was <X-1>.

...how much profit will Firm A earn? Recall that profit is equal to (Firm A's price × number of units Firm A sold) - ($9 × number of units Firm A ordered). You said: [subject's input]

That is correct.

Comprehension Questions, Page 5b (screen shown when subject's answer was incorrect)

Suppose Firm A orders <X> unit(s) and sets a price of $<Y> while Firm B sets a price of $<Z>.

If <X-1> buyer(s) visit Firm A,

...how many units will Firm A sell? You said: [subject's input]

...The correct answer was <X-1>.

...how much profit will Firm A earn? Recall that profit is equal to (Firm A's price × number of units Firm A sold) - ($9 × number of units Firm A ordered). You said: [subject's input]

That is incorrect. The correct answer is <(Y*(X-1) -9*(X))>. To find Firm A's profit, we multiply the price it charges, <Y>, by the number of units sold, <X-1>, and then subtract the costs that Firm A incurs for ordering units. Since Firm A is charged $9 for each unit it orders, and since Firm A ordered <X> units, these costs are 9 x <X>, or <9*X>. Therefore, the total earnings of Firm A is <Y> x <X-1> - 9 x <X> = <(Y*(X-1) - 9*(X))>.

Comprehension Questions, Page 6

Suppose Firm A orders <X> unit(s) and sets a price of $<Y> while Firm B sets a price of $<Z>.

If <X-1> buyer(s) visit Firm A,

...how many units will Firm A sell? You said: [subject's input]

...The correct answer was <X-1>.

...how much profit will Firm A earn? Recall that profit is equal to (Firm A's price × number of units Firm A sold) - ($9 × number of units Firm A ordered). You said: [subject's input]

...The correct answer was <(Y*(X-1) - 9*(X))>.

...how much profit will a buyer who visits Firm A earn?

Comprehension Questions, Page 7a (screen shown when subject's answer was correct)

Suppose Firm A orders <X> unit(s) and sets a price of $<Y> while Firm B sets a price of $<Z>.

If <X-1> buyer(s) visit Firm A,

...how many units will Firm A sell? You said: [subject's input]

...The correct answer was <X-1>.

...how much profit will Firm A earn? Recall that profit is equal to (Firm A's price × number of units Firm A sold) - ($9 × number of units Firm A ordered). You said: [subject's input]

...The correct answer was <(Y*(X-1) - 9*(X))>.

...how much profit will a buyer who visits Firm A earn? You said: [subject's input]

That is correct.

Comprehension Questions, Page 7b (screen shown when subject's answer was incorrect)

Suppose Firm A orders <X> unit(s) and sets a price of $<Y> while Firm B sets a price of $<Z>.

If <X-1> buyer(s) visit Firm A,

...how many units will Firm A sell? You said: [subject's input]

...The correct answer was <X-1>.

...how much profit will Firm A earn? Recall that profit is equal to (Firm A's price × number of units Firm A sold) - ($9 × number of units Firm A ordered). You said: [subject's input]

...The correct answer was <(Y*(X-1) - 9*(X))>.

...how much profit will a buyer who visits Firm A earn? You said: [subject's input]

This is incorrect. The correct answer is <15 - Y>. To calculate how much an individual will profit from purchasing a unit we take how much they value the good and subtract the price that is charged. In this case, the buyer values Firm A's product at $15 and Firm A decided to set a price of $<Y>. Therefore the profit to a buyer who buys from Firm A is the difference between these two values: 15 - <Y>, or <15 - Y>.

Comprehension Questions, Page 8

Suppose Firm A orders <X> unit(s) and sets a price of $<Y> while Firm B sets a price of $<Z>.

If <X + 1> buyers visit Firm A,

...how many units will Firm A sell?

Comprehension Questions, Page 9a (screen shown when subject's answer was correct)

Suppose Firm A orders <X> unit(s) and sets a price of $<Y> while Firm B sets a price of $<Z>.

If <X + 1> buyers visit Firm A,

...how many units will Firm A sell? You said: [subject's input]

That is correct.

Comprehension Questions, Page 9b (screen shown when subject's answer was incorrect)

Suppose Firm A orders <X> unit(s) and sets a price of $<Y> while Firm B sets a price of $<Z>.

If <X + 1> buyers visit Firm A,

...how many units will Firm A sell? You said: [subject's input]

That is incorrect. The correct answer is <X>. If Firm A orders fewer units than it has buyers visit then it will sell all the units it ordered. Since Firm A ordered <X> unit(s) and <X + 1> buyers visited, Firm A would have been able to sell all <X> of its units.

Comprehension Questions, Page 10

Suppose Firm A orders <X> unit(s) and sets a price of $<Y> while Firm B sets a price of $<Z>.

If <X + 1> buyers visit Firm A,

...how many units will Firm A sell? You said: [subject's input]

The correct answer was <X>.

...how much profit will Firm A earn?

Comprehension Questions, Page 11a (screen shown when subject's answer was correct)

Suppose Firm A orders <X> unit(s) and sets a price of $<Y> while Firm B sets a price of $<Z>.

If <X + 1> buyers visit Firm A,

...how many units will Firm A sell? You said: [subject's input]

The correct answer was <X>.

...how much profit will Firm A earn? You said: [subject's input]

That is correct.

Comprehension Questions, Page 11b (screen shown when subject's answer was incorrect)

Suppose Firm A orders <X> unit(s) and sets a price of $<Y> while Firm B sets a price of $<Z>.

If <X + 1> buyers visit Firm A,

...how many units will Firm A sell? You said: [subject's input]

The correct answer was <X>.

...how much profit will Firm A earn? You said: [subject's input]

That is incorrect. The correct answer is <(Y*X - 9*X)>. To find Firm A's profit, we multiply the price it charges, <Y>, by the number of buyers who visit the store and can purchase, <X>, and then subtract the costs that Firm A incurs for ordering units. Since Firm A is charged $9 for each unit it orders, and since Firm A ordered <X> units, these costs are 9 x <X>, or <9*X>. Therefore, the total earnings of Firm A is <Y> x <X> - 9 x <X> = <(Y*(X) - 9*(X))>.

Comprehension Questions, Page 12

Suppose Firm A orders <X> unit(s) and sets a price of $<Y> while Firm B sets a price of $<Z>.

If <X + 1> buyers visit Firm A,

...how many units will Firm A sell? You said: [subject's input]

The correct answer was <X>.

...how much profit will Firm A earn? You said: [subject's input]

...The correct answer was <(Y*X - 9*X)>.

...how much profit will a buyer who actually buys a unit from Firm A earn?

Comprehension Questions, Page 13a (screen shown when subject's answer was correct)

Suppose Firm A orders <X> unit(s) and sets a price of $<Y> while Firm B sets a price of $<Z>.

If <X + 1> buyers visit Firm A,

...how many units will Firm A sell? You said: [subject's input]

The correct answer was <X>.

...how much profit will Firm A earn? You said: [subject's input]

...The correct answer was <(Y*X - 9*X)>.

...how much profit will a buyer who actually buys a unit from Firm A earn?

You said: [subject's input]

That is correct.

Comprehension Questions, Page 13b (screen shown when subject's answer was incorrect)

Suppose Firm A orders <X> unit(s) and sets a price of $<Y> while Firm B sets a price of $<Z>.

If <X + 1> buyers visit Firm A,

...how many units will Firm A sell? You said: [subject's input]

The correct answer was <X>.

...how much profit will Firm A earn? You said: [subject's input]

...The correct answer was <(Y*X - 9*X)>.

...how much profit will a buyer who actually buys a unit from Firm A earn?

You said: [subject's input]

That is incorrect. The correct answer is <15 - Y>. To calculate a buyer's profit we take the value the buyer has for the good and subtract how much the buyer paid for the good. Since this buyer bought from Firm A, the value of the good is 15, and the price was <Y>. Therefore the buyer's profit is 15 - <Y>, or <15 - Y>.

Comprehension Questions, Page 14

Suppose Firm A orders <X> unit(s) and sets a price of $<Y> while Firm B sets a price of $<Z>.

If <X + 1> buyers visit Firm A,

...how many units will Firm A sell? You said: [subject's input]

The correct answer was <X>.

...how much profit will Firm A earn? You said: [subject's input]

...The correct answer was <(Y*X - 9*X)>.

...how much profit will a buyer who actually buys a unit from Firm A earn?

You said: [subject's input]

...The correct answer was <15 - Y>.

...what happens to a buyer who visits Firm A but is unable to purchase a unit?

Button: {"Has the option to visit Firm B"; "Is unable to purchase in this period"}

Comprehension Questions, Page 15a (screen shown when subject's answer was correct)

Suppose Firm A orders <X> unit(s) and sets a price of $<Y> while Firm B sets a price of $<Z>.

If <X + 1> buyers visit Firm A,

...how many units will Firm A sell? You said: [subject's input]

The correct answer was <X>.

...how much profit will Firm A earn? You said: [subject's input]

...The correct answer was <(Y*X - 9*X)>.

...how much profit will a buyer who actually buys a unit from Firm A earn?

You said: [subject's input]

...The correct answer was <15 - Y>.

...what happens to a buyer who visits Firm A but is unable to purchase a unit?

You said: [subject's input]

That is correct.

Comprehension Questions, Page 15b (screen shown when subject's answer was incorrect)

Suppose Firm A orders <X> unit(s) and sets a price of $<Y> while Firm B sets a price of $<Z>.

If <X + 1> buyers visit Firm A,

...how many units will Firm A sell? You said: [subject's input]

The correct answer was <X>.

...how much profit will Firm A earn? You said: [subject's input]

...The correct answer was <(Y*X - 9*X)>.

...how much profit will a buyer who actually buys a unit from Firm A earn?

You said: [subject's input]

...The correct answer was <15 - Y>.

...what happens to a buyer who visits Firm A but is unable to purchase a unit?

You said: [subject's input]

That is incorrect. If a buyer is unable to buy a unit from Firm A it will not have the opportunity to visit Firm B in the same period.

Comprehension Questions, Page 16

Suppose Firm A orders <X> unit(s) and sets a price of $<Y> while Firm B sets a price of $<Z>.

If <6 - X + 1> buyers visit Firm B,

...how much profit will Firm B earn?

Comprehension Questions, Page 17a (screen shown when subject's answer was correct)

Suppose Firm A orders <X> unit(s) and sets a price of $<Y> while Firm B sets a price of $<Z>.

If <6 - X + 1> buyers visit Firm B,

...how much profit will Firm B earn? You said: [subject's input]

That is correct.

Comprehension Questions, Page 17b (screen shown when subject's answer was incorrect)

Suppose Firm A orders <X> unit(s) and sets a price of $<Y> while Firm B sets a price of $<Z>.

If <6 - X + 1> buyers visit Firm B,

...how much profit will Firm B earn? You said: [subject's input]

That is incorrect. The correct answer is <(6 - X + 1)*Z>. To calculate Firm B's profit, we multiply how many buyers visit Firm B, <6 - X + 1> by the price that Firm B set, <Z>. This gives us <6 - X + 1> x <Z>, or <(6 - X + 1)*Z>.

Comprehension Questions, Page 18

Suppose Firm A orders <X> unit(s) and sets a price of $<Y> while Firm B sets a price of $<Z>.

If <6 - X + 1> buyers visit Firm B,

...how much profit will Firm B earn? You said: [subject's input]

...The correct answer was <(6 - X + 1)*Z>.

...how much profit will a buyer who visits Firm B earn?

Comprehension Questions, Page 19a (screen shown when subject's answer was correct)

Suppose Firm A orders <X> unit(s) and sets a price of $<Y> while Firm B sets a price of $<Z>.

If <6 - X + 1> buyers visit Firm B,

...how much profit will Firm B earn? You said: [subject's input]

...The correct answer was <(6 - X + 1)*Z>.

...how much profit will a buyer who visits Firm B earn? You said: [subject's input]

That is correct.

Comprehension Questions, Page 19b (screen shown when subject's answer was incorrect)

Suppose Firm A orders <X> unit(s) and sets a price of $<Y> while Firm B sets a price of $<Z>.

If <6 - X + 1> buyers visit Firm B,

...how much profit will Firm B earn? You said: [subject's input]

...The correct answer was <(6 - X + 1)*Z>.

...how much profit will a buyer who visits Firm B earn? You said: [subject's input]

That is incorrect. To calculate how much profit a buyer will earn from visiting Firm B take the value of Firm B's product, 9 and subtract the price charged by Firm B, <Z>. Therefore, the profit earned by the buyer would be 9 - <Z>, or <9 - Z>.

Comprehension Questions, Page 20

We are now ready to begin the experiment. If you do not have any questions, please click the BEGIN button below.